Ontario

THE REPORT OF THE

Royal Commission on Electric Power Planning

Chairman: Arthur Porter

VOLUME 3

Factors Affecting the Demand for Electricity in Ontario

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The Report of the Royal Commission on Electric Power Planning

List of Volumes

The Report of the Royal Commission on Electric Power Planning is comprised of the following volumes:

Volume 1: Concepts, Conclusions, and Recommendations

Volume 2: The Electric Power System in Ontario

Volume 3: Factors Affecting the Demand for Electricity in Ontario

Volume 4: Energy Supply and Technology for Ontario

Volume 5: Economic Considerations in the Planning of Electric Power in Ontario

Volume 6: Environmental and Health Implications of Electric Energy in Ontario

Volume 7: The Socio-Economic and Land-Use Impacts of Electric Power in Ontario

Volume 8: Decision-Making, Regulation, and Public Participation: A Framework for Electric Power Planning in Ontario for the 1980s

Volume 9: A Bibliography to the Report

VOLUME 3

Factors Affecting the Demand for Electricity in Ontario

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The authors wish also to thank the staff of the Load Forecasting Section, Ontario Hydro, for their help in preparing Chapter 3. In particular, L.G. Higgins and J. Heller gave generously of their time and patience to explain their forecasting procedure.

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Foreword

The Commission wishes to acknowledge the contributions to our Report made by the authors of this volume. The enormity of the task as well as the skill and tenacity with which it was performed are testimony to the talents of Dr. James E. Dooley, Michael Jaffey, and Dr. Erik F. Haites. Our work would have been immeasurably more difficult without their assistance.

This volume, *Factors Affecting the Demand for Electricity in Ontario*, focuses on a key issue area raised by the public during the Commission's public hearings process. The analysis, conclusions, and recommendations reflect data received by the Commission in the form of public testimony and exhibits, consultants' reports, and independent research and analysis by the authors. We have relied heavily on this work in formulating our own conclusions and recommendations in Volume 1. However, the views expressed in this volume are ultimately the responsibility of the authors. This document is therefore best viewed as a background paper which attempts to draw together the detailed evidence and analysis available on this complex subject, in a fashion which will be of use to the general public as well as to the technical community.

The research and evolution of this document were directed and reviewed for the Commission by Philip A. Lapp and Peter G. Mueller.

Arthur Porter, Chairman.

Executive Summary

The demand for electricity must be studied as part of the demand for energy. The wide range of possible substitutions among energy forms in the long run makes this essential. The factors that affect the demand for energy may be classified as demographic variables, economic growth variables, and energy-intensity variables. Energy-intensity variables include anything that reduces the energy consumed per dollar of real gross domestic product (GDP). This includes two types of effects: efficiency improvements that reduce the energy required for a given production or consumption activity and structural changes that shift production or consumption from more to less energy-intensive patterns.

The population of Ontario in 2001 is forecast at 10.55 million, which implies a rate of growth of 1 per cent per year. The age structure of the population is such that employment will increase more rapidly than the population. Employment is projected to grow at an average annual rate of 1.6 per cent. The historic rate of increase of productivity in Ontario is 1.7 per cent per year. No compelling reason is found to project higher or lower rates of productivity growth in the future. The real domestic product of Ontario is therefore projected to grow at an average rate of 3.3 per cent per year to the year 2000.

Energy intensity is measured as the difference between the annual rate of growth of real gross domestic product and energy demand. A number of specific conservation measures that are likely to be implemented before 2000 are identified. Together, these measures bring the growth in demand for energy down below what it would otherwise be by 1.55 per cent per year. The preferred projection of the rate of growth of demand for energy in Ontario to 2000 is 1.75 per cent per year.

Ontario Hydro requires an elaborate set of forecasts of demand for electricity. They must forecast both peak and energy demands. They must extend far enough into the future to cover the planning and construction of new generating facilities and they must be subdivided into relatively small geographical areas. Until the early 1970s, Ontario Hydro's forecasting performance was outstanding by any measure. More recent forecasts are much poorer, suggesting that the traditional methods are no longer completely satisfactory.

The medium-term forecast is based on forecasts supplied by public utility commissions and direct industrial customers and on a forecast prepared with an econometric model. The overall quality of the forecast supplied by the PUCs and direct industrial customers is lower than is desirable. There is no practical alternative source of geographically disaggregated forecasts. The econometric model has some disturbing aspects that have not been resolved. Techniques that might have resolved these problems were not tested.

A number of comprehensive energy demand models for Canada and Ontario are reviewed. Despite the diversity of the models, the projections are remarkably similar. The rate of growth of demand for energy in Ontario is generally projected to range between 2.0 and 3.0 per cent per year. The forecast rates of growth of demand for electricity lie between 2.0 and 5.5 per cent per year.

A model that relates the demand for electricity to the demand for energy in Ontario is developed. It determines the feasible combinations of growth rates of demand for conventional fuels. It classifies the demands for energy as captive to a specific form of energy or substitutable among different forms of energy. Roughly half of the energy demand is captive to specific fuels. Finally, the model relates each rate of growth of demand for each form of energy to the market shares of the substitutable applications in the year 2000.

The preferred projection is based on a 1.75 per cent per year rate of growth of secondary energy demand in Ontario to 2000. It also anticipates that 2 per cent of the secondary energy demand in 2000 will be met by renewable energy sources. Constraints relating to the available supplies of oil and natural gas and the possible applications for coal and electricity are applied. The resulting projection of the rate of growth of demand for electricity in Ontario to 2000 is 3.25 ± 0.5 per cent per year.

CHAPTER ONE

Introduction

The Scope of the Study

In December 1976, the RCEPP published *The Demand for Electric Power* as the second in a series of issue papers. This paper emphasized that the demand for electric power was central to the Commission's inquiry. A summary of it prepared by the Commission outlined the issue as follows:

> How much electricity will we be using in the future? This is indeed a complex question. Future demand for electricity is closely related to population growth, commercial activity, and industrial development, as well as to the availability of primary fuels at reasonable prices, to conservation measures, and many other factors.[1]

A great deal of testimony has been heard by the Commission and much research has been undertaken since the paper was published, but the above description remains an excellent summary of the issue.

The purpose of this study is to review the factors affecting the demand for electricity in Ontario to the year 2000. More specifically, it draws upon the relevant testimony and research to review the factors affecting the demand for energy in Ontario, project the demand for energy and for electricity in the province to the year 2000, and examine the load-forecasting methodology employed by Ontario Hydro.

The Organization of the Study

The demand for electricity must be studied as part of the demand for energy. Electricity is one of several forms of energy that are widely used in the province. Petroleum, natural gas, and coal are the others. In many applications, electricity can readily be substituted for other energy forms, and vice versa. Over the 20-year horizon that is the principal focus of this study the range of possible substitutions is great. A complete analysis of the likely future demand for electricity, therefore, requires an analysis of the demand for energy.

It is convenient to classify the factors that affect the demand for energy as demographic variables, economic growth variables, and energy intensity variables. This classification will be employed throughout the study. Each of these groups of variables is discussed at some length in Chapter 2.

Energy intensity relates the energy consumed to the real gross domestic product. Conceptually, a reduction in energy intensity includes two types of effects: efficiency improvements – changes that reduce the energy required for a given production or consumption activity; and structural changes – shifts from more to less energy-intensive production or consumption patterns. The popular concept of conservation corresponds roughly to this definition of energy-efficiency improvement.

Studies of future energy demands generally cover a relatively long period, typically 10 to 50 years. A long-time horizon is necessary because of the long lead times needed to construct energy supply and distribution facilities and because of the long time needed to replace or convert the existing stock of energy-using equipment.

The long-time horizon affects the selection of variables and the study methods. For example, detailed economic models become less reliable as the forecast period increases. Thus, studies of energy demand use less detailed economic models designed for long-term forecasting, and they usually relate energy demand to a few demographic and aggregate economic variables.

Projected Growth of Demand for Electricity in Ontario to 2000

The rate of growth of demand for electricity in Ontario to 2000 plays a major role in defining the electric power planning needs over this period. To assess the possible rates of growth of demand for electricity, this study reviews Ontario Hydro's load-forecasting process (Chapter 3), reviews a number of comprehensive models of energy demand (Chapter 4), and develops a relatively simple model of energy demand in Ontario (Chapter 5).

The model is used to project the rate of growth of demand for electric energy in Ontario to 2000. It must be stressed that the results are projections not forecasts. For the purposes of this study, a forecast is defined as an attempt to predict what will happen, whereas a projection attempts to indicate what would happen if certain assumed conditions were satisfied.

The preferred projection is based on estimates of the probable demographic and economic growth in Ontario. It yields average annual growth rates to 2000 of 1 per cent for population, 3.3 per cent for real GDP, 1.75 per cent for total secondary energy demand, and 3.25 ± 0.5 per cent for demand for electrical energy. These are average annual growth rates for the next 20 years. Growth rates for individual years may lie above or below the average.

Public Concerns

Many submissions to the Commission expressed concern about the future demand for energy, and, more specifically, the future demand for electricity. Concerns were expressed by individuals, by a wide range of interest groups – agricultural, residential, commercial, private, and industrial – and by the federal and provincial governments. The concerns were usually expressed in broad, general terms. Almost all of the submissions suggested that greater effort should be put into conservation, to limit the future demand for energy and electricity.

Population

Few submissions discussed the relationship between population growth and energy demand. That of Zero Population Growth Inc. was one that did. This group contended that a lower rate of population growth would reduce the growth of energy demand.[2] Specifically, it predicted that a reduction of 0.2 per cent in the rate of population growth would lower the rate of growth of demand for electricity by 0.7 per cent. It also contended that "recent economic reports indicate that reduced migration to Ontario in the future would not be harmful to the province's economic development as has been alleged."[3]

Professor Robert Paehlke of Trent University also discussed the relationship between population and energy demand. He stated that "the bulk of the growth rate of energy demand is attributable to population growth. It has been considerably more rapid than population growth."[4] He suggested that the rate of population growth be controlled by restricting immigration. This would help control the growth of energy demand.

Economic Growth

The economic growth of a society is often considered to be directly related to its energy consumption. The Electrical and Electronic Manufacturers' Association of Canada (EEMAC) asserted that "it has been recognized for many years that economic trends in Ontario and elsewhere are closely related to the rate of growth in use of electricity".[5] This relationship is taken for granted by many of the industrial interest groups and individuals who favour continued high economic growth. Organizations such as the Canadian Manufacturers' Association (CMA), the EEMAC, and the Canadian Nuclear Association (CNA), to mention the main ones, presented the view that, to remain healthy, the economy must continue to grow at historic rates. This would require that the consumption of electricity grow at the historic rate of 6 to 7 per cent. Such a growth rate includes a large amount of conversion from natural gas and oil to electricity. The associations anticipate that the rate of conversion to electricity will increase over the next few years.

Many public interest groups and individuals argued that high rates of growth of energy consumption are not essential for economic growth. *Alternatives* magazine made the point this way:

> On a more general level, it is usually assumed that overall energy growth is essential for continued economic expansion, perhaps looking to the pattern of the past which has seen energy and economic growth running roughly parallel. But the great disparities in per capita energy consumption among nations with approximately equal economic output per capita are a powerful argument against assuming the necessity of such a linkage. That is, some countries get far more (in terms of economic output) out of the energy they consume than do others. Most get more than Canada gets.[6]

The Conservation Council of Ontario also recognized the historic relationship between energy growth and economic growth. It argued that this relationship could not continue to hold because of the declining supplies and rising prices of fossil fuels. The Sierra Club of Ontario expressed the view that "the energy/GNP relationship . . . has not been a fixed ratio in the past although it has been fairly constant, and will not necessarily be a fixed ratio in the future".[7]

One of the reasons why these two groups differ in their assessment of the future relationship between energy consumption and economic growth is their respective views on the relationship between energy consumption and employment. The first group (EEMAC, CNA, CMA) felt that, to achieve a high rate of

economic growth, productivity – output per worker – must rise. They argued that increased productivity will require the use of advanced technology and more automated equipment. This will require more energy per worker.

The second group (Sierra Club of Ontario, Energy Probe, *Alternatives*, Conservation Council of Ontario) argued that current methods of using energy are wasteful and that conservation programmes are necessary to reduce energy consumption and increase employment. They suggested that the net effect of conservation programmes on the economy may be higher employment, because they would create employment in the manufacture of insulation and energy-saving devices, the operation of public transportation facilities, and so on. This might offset employment lost due to lower economic growth resulting from the use of more automated equipment. The submission by *Alternatives*, for example, stated that "there is mounting evidence, not only that the linkage of energy growth and job creation is fallacious, but that measures to conserve energy may actually *increase* employment".[8]

Conservation

Conservation, defined as the more efficient use of energy, was discussed in a large number of submissions to the RCEPP. All of them supported it. Differences arose when the discussion turned to the best means of encouraging conservation – price increases, regulations, or public information campaigns. Opinions on the probable impact of conservation measures on life-styles also differed.

Industrial interest groups such as the EEMAC and the CMA were in favour of conservation. But it was their opinion that conservation efforts would yield only a one-time gain. Once efficiency levels had improved no further gains would be possible. For this reason, they argued, the success of efforts to reduce the rate of growth of energy demand would depend ultimately on the acceptance of a significantly more austere life-style.

On the other hand, the "public interest groups" contended that conservation measures could dramatically reduce the rate of growth of energy demand without adversely affecting life-styles. The Canadian Coalition for Nuclear Responsibility, for example, stated that

> an energy policy based on improved energy efficiency (which means cutting out mindless waste), energy conservation (which means a reduction in demand), and a transition to the use of renewable energy sources would require policies of our institutions, but it would lead to an improved quality of life for Ontario citizens, *without significant changes in our life-style or our basic freedoms.*[9]

Two public interest groups presented detailed submissions on the consequences of conservation measures. The Sierra Club of Ontario tabled a study entitled "The Impact of Energy Conservation Measures on Ontario's Load Growth". Energy Probe of Toronto advocated a steady-state economy – an economy with zero energy growth. This group presented a detailed study indicating how this could be achieved by 2025. There would be some growth in energy demand during the transition period, but no need to lower the standard of living.

There was unanimous agreement on the need for public education on energy matters. There were differences of opinion as to who should do the educating, how it should be done, and where it should start. The Grade 4 class of Baythorn Public School, Thornhill, felt that education on energy and conservation should start in kindergarten. Their teacher, Mrs. L.E. Ayres, felt that starting the education programme after Grade 4 would not have any effect. She, and many others, felt that information on energy should be a fundamental part of the school curriculum through all grades.

Many people expressed a need for more information, and indicated that they had been unable to find it. The government was often mentioned as the most suitable agency to head up an education programme on the wise use of energy.

Education on energy matters, while desirable, will have only a limited impact. Many people testified that they were prepared to take measures such as turning down thermostats, turning out unnecessary lights and adding insulation – things that can be done easily with no change in life-style. These people were much more reluctant to make more difficult changes such as switching to public transportation from private automobiles. Similarly, a number of farmers expressed reluctance to return to pumping water by means of windmills after having experienced the convenience of electric pumps.

As evidence of the public's lack of commitment to conservation measures, EEMAC cited the difficulty in selling energy-efficient appliances. These appliances cost more initially but have lower operating costs because they are more energy-efficient. EEMAC felt that buyers base their decisions on the purchase

price rather than the life-cycle cost. Hence, manufacturers had little incentive to make appliances more efficient.

Stronger measures are needed for a serious conservation effort. Public education on energy matters found universal favour. But it was also universally acknowledged that public education alone would yield only limited reductions in energy demand.

Two types of conservation measures were proposed – higher energy prices and government regulation of energy use. Some groups noted the substantial reductions in the rate of growth of energy demand since 1973, when prices started to rise. They noted that energy prices in Ontario are still well below world levels and felt that further reductions in demand will occur as our prices approach world levels. Price increases, they argued, were enough to produce the necessary conservation efforts.

Other groups were not as willing to rely strictly on the price mechanism. They cited the number of lights on in office towers at night. The firms involved might well be able to afford to leave the lights on. But wasteful practices such as this are inequitable if there are shortages or people who cannot afford the electricity they need for essential purposes. Government regulations for insulation, fuel economy for automobiles, energy efficiency for appliances, and so on, were advocated to supplement the price mechanism and reduce the rate of growth of energy demand.

Summary

The demand for electricity must be studied as part of the demand for energy. The wide range of possible substitutions among the various forms of energy makes this essential. The factors that affect the demand for energy may be classified as demographic variables, economic growth variables, and energy-intensity variables. Variables that lower the energy intensity include anything that reduces the energy consumed per dollar of real gross domestic product. This includes two types of effects: efficiency improvements that reduce the energy required for a given production or consumption activity; and structural changes that shift production or consumption to patterns that are less energy-intensive.

The public concerns that were conveyed to the Commission focused on the relationship between economic growth and energy demand and on energy conservation. Some submissions argued that high rates of growth of energy consumption are essential for high rates of economic growth. Other submissions argued to the contrary, that low rates of growth of consumption of conventional forms of energy will stimulate economic growth because of the demands for conservation and renewable energy.

The public submissions unanimously favoured conservation as long as there was no adverse impact on life-styles. Some groups felt that conservation efforts would produce only a one-time gain in the efficiency of energy use. Others felt that continuous improvements were possible.

CHAPTER TWO

Factors Affecting the Demand for Electricity

Conceptual Framework

A basic premise of this study is that the demand for electricity must be analysed in the context of the demand for energy. Electricity is only one of several forms of energy that are widely used in the province. Petroleum, natural gas, and coal are the other major ones.

In many applications, electricity can readily be substituted for other energy forms, and vice versa. Over the 20-year horizon of this study the range of possible substitutions is great. Forecasts of energy supply and demand for the world indicate that oil shortages are likely to occur before 2000. The forecasts differ primarily in their predictions of the sizes of the shortages and how soon they will start. Energy forecasts for Canada yield similar results. Oil shortages are likely to occur before 2000 and possibly as early as 1985. These shortages would result in a reduced rate of growth of energy demand and some substitution of electricity for oil. A complete analysis of the demand for electricity, therefore, requires an analysis of the demand for energy.

The demand for energy is analysed in terms of the amount of energy needed during a given period, usually one year. For example, energy is required for a specific task such as heating water for a given type of home for a year. This task can be performed using electricity, oil, or natural gas. The amount of energy required may not be the same in each case because different types of water heaters may have different efficiencies. Substitution of electric water heaters for oil water heaters would increase the amount of electric energy demanded and reduce the amount of oil demanded, although not necessarily by the same amount.

Ontario Hydro focuses its forecast on the annual peak demand for electricity. While utilities can store some electric energy in hydraulic form to assist in meeting peak demands, generating facilities are usually planned so that they will supply most if not all peak demands when they occur. A mix of so-called peak-load, intermediate-load, and base-load generating capacity and transmission facilities is selected to meet the forecast daily, weekly, and annual fluctuations in demand most economically with the specified degree of reliability.

At present, Ontario Hydro's load forecasters assume that the daily, weekly, and annual fluctuations in demand will follow the historical pattern. This means that the relationship between the annual peak demand and the total electric energy demand remains unchanged. The total electric energy demand is a major input into other calculations, such as the amounts of coal and uranium that will be required.

The forecast of peak demand does not lend itself to an analysis of the possible substitution of other energy forms for electricity, or vice versa. The substitution possibilities are best analysed in terms of the annual energy demand. In our view, the substitution possibilities are an important element in any forecast of the demand for electricity. Hence, the principal focus of this study is the total demand for electric energy during a given year. The peak demand can be estimated from the annual demand by applying the forecast load factor.

Studies of future energy demand generally cover a relatively long period, typically 10 to 50 years. This time horizon is necessary because of the long lead times needed for the construction of energy supply and distribution facilities, and because of the time needed to replace or convert the existing stock of energy-using equipment. It also permits an evaluation of the long-run consequences of proposed policies.

The long-time horizon affects the forecasting methods and the selection of variables. Generally, a study produces a demographic projection first, followed by an economic projection, and then an energy demand projection. This is illustrated in Figure 2.1.

Fig. 2.1: p. 18

The population projection is made by a technique called the component method, which forecasts births, deaths, and net migration during a specified period (one to five years). These components are used to adjust the population at the start of the period and so yield the population at the end of the period.

The traditional method of projecting long-run economic growth is to estimate the growth in employment and increases in productivity. The projected labour force is calculated from the working-age

population by using participation rates. Adjusting the labour force for the level of unemployment yields the projected employment.

Increases in productivity are usually forecast on the basis of past experience. This introduces the implicit assumption that the nature of economic development in the future will be similar to that experienced in the past. If the nature of economic development is expected to change, the historic rates of productivity growth can be adjusted to reflect this change. An expectation that consumers are becoming saturated, for example, would be reflected in lower rates of productivity increase per worker. The lower rates reflect a shift in preference from more income to more leisure time.

Some studies use large econometric models to make the economic projection. In the past, such models were not considered reliable for longer-term forecasting. Recent improvements in model-building techniques have allowed the development of econometric models that are judged by some to be reliable for forecasting up to 10 or 15 years.

There are no universally accepted measures of the change in energy intensity. The most common aggregate measure is the ratio of the rate of growth of energy demand to the rate of real economic growth. For reasons discussed later in this chapter we prefer a variation of this measure – the rate of real economic growth less the rate of growth of energy demand.

This aggregate measure of change in energy intensity embraces two conceptually different effects: energy-efficiency improvements, or conservation; and changes in the structure of society. An example of the former is the increased fuel efficiency of automobiles. An example of the latter is the fact that the age structure of Canadian society is shifting upwards, and as a consequence the rate of new household formation will be lower during the next two decades than it was over the last 20 years. This, in turn, means that the rate of growth of energy demand for residential space heating and water heating will be lower during the next 20 years than it has been, provided that the energy demand per household for these purposes does not rise dramatically.

Similarly, a change in the structure of society could lead to higher rather than lower energy consumption. In recent years, the number of people in the 15 to 30 age group has been growing rapidly. At this age people typically buy their first car. The growth in the size of this age group has contributed to the increase in the stock of automobiles and to the associated increase in energy consumption. The aggregate energy intensity measure is the net effect of conservation efforts and increases and decreases in energy demand due to structural changes. The conceptual framework shown in Figure 2.1 excludes secondary effects.

It is well known, for example, that economic conditions affect fertility rates and net migration. This feedback effect is ignored, as it is in most models. Similarly, the economic consequences of a given rate of growth of energy demand may affect the rate of economic growth. Again, it is the practice of most models to ignore this effect.

These secondary effects are excluded because they are estimated to be small relative to the margin of error for the projection, and because they introduce an iterative process that may take a long time to stabilize, and hence, are difficult to build into a model.

Demographic Variables

The demographic variables that make up long-term population growth are fertility rates, mortality rates, and net migration (in-migration and out-migration). Relative to birth rates and migration, mortality rates are stable. The stability of the mortality rates makes them easy to project, using historical data.

Differences with respect to fertility rates and net migration account for most of the differences between population projections. If the total population is large, and the fertility rate is above the long-term replacement level, the fertility rate assumptions have a greater impact on the population projection than the net migration assumptions. If the population is small or the fertility rate is below the long-term replacement level, the net migration assumptions have the greater impact. Over the last 25 years, natural increase has accounted for 57 per cent of Ontario's population growth. The remaining 43 per cent has been due to migration.

Fertility

The total fertility rate (TFR) is a convenient overall measure of fertility. It is the number of children a woman will have throughout her lifetime if she experiences at each age the fertility in effect during the period concerned. To illustrate, assume that we are using five-year periods and that the woman is in the 15-19 age group during the first period. The TFR at the start of the first period is compiled by summing the fertility rate for women 15-19 during the first period, the fertility rate for women 20-24 during the second period, the fertility rate for women 25-29 during the third period, and so on.

In Ontario, as elsewhere in Canada, the total fertility rate has been dropping steadily for 15 years. At its peak in 1961 the total fertility rate in Ontario was 3.2; now it is 1.75. With no migration, a total fertility rate of about 2.1 is needed to maintain a stable population in the long run.

The most recent Ontario government population projections are based on the following fertility rate assumptions:[1]

- high: declining to 1.75 in 1981, rising slowly to 2.1 in 2001
- medium: declining to 1.70 in 1986 then rising to 1.80 in 2001
- low: declining to 1.50 in 1996 and constant thereafter

The low fertility assumption, even with no net migration, will increase Ontario's population by almost one million by 2001. The population increase occurs even though the assumed TFR is well below the long-run population maintenance TFR of 2.1. The explanation lies in the age structure of the population. At present a relatively high proportion of the women are of child-bearing age. So a low fertility rate still leads to a population increase.

Migration

Ontario's population is affected both by international migration and by interprovincial migration. Historically, just over half of the immigrants to Canada have settled in Ontario. Data on emigration from Canada are poor. Emigration estimates are based on the residual differences from one census to the next. During the past 25 years the net gain to Ontario from foreign migration has ranged from 9,000 to 101,000 and has averaged 46,000 persons per year.

Annual estimates of interprovincial migration are only available for the past decade or so. These estimates are based on changes of address for family allowance payments. Previously, interprovincial migration had to be estimated from differences between one census and the next.

Over most of the period from 1920 to the early 1970s, Ontario gained population as a result of interprovincial migration. But the traditional patterns are changing. During the mid 1970s the net inflow from the Atlantic provinces declined and there was a large net outflow to Alberta and British Columbia. As a result, Ontario lost about 20,000 people per year via interprovincial migration. In the last few years, the inflow from Quebec has increased. Together with the other inflows, this approximately balanced the losses to the west.

Net migration into Ontario has varied from a high of 130,000 in 1956 to a low of 20,000 in 1978. A very high level of immigration into Canada combined with a net gain from interprovincial migration to produce the 1956 record. Despite the levels of immigration into Canada and the increased outflows to other provinces, Ontario still reaps a net gain from migration. The net gain averaged 50,000 people per year from 1971 to 1976. More recently it has averaged about 30,000 people per year.

Studies indicate that the levels of international and interprovincial migration are affected by many factors, including:

- the average age of the population in the originating area. Young persons are more likely to migrate.
- economic conditions in the originating area
- economic conditions at the destination
- similarity of language and culture in the two areas
- the size of previous migratory flows. The higher the past levels of migration the more likely a future migrant is to have friends or relatives near his new home.
- the existence of barriers, such as quotas for international migration

The number and complexity of the factors that affect migration into and out of Ontario make accurate forecasting of these flows an impossible task.

The most recent Ontario government population projections assume net migration into the province of

30,000 per year to 2000.[2] Recent experience was chosen as the basis for the forecast because the government demographers could find no strong reason to support a higher or lower value.

Population Growth

Currently, the preferred projection of the provincial government demographers is a population of 10.1 million in 2001. This is an increase of 1.85 million from the 1976 population of 8.26 million. This population projection implies an average annual rate of growth of 0.8 per cent. From 1957 through 1976 the rate of population growth in Ontario averaged 2.4 per cent per year. The projected rate of population growth, then, is well below that of the recent past.

At the time the RCEPP's *Interim Report on Nuclear Power in Ontario* was prepared (1978), the preferred projection of the provincial government demographers was 11.6 million people in 2001. That projection assumed annual net migration of 50,000. Reducing this to 30,000 accounts for half of the 1.5 million reduction in the projected 2001 population. The other half of the reduction is due to different fertility rate assumptions. The previous projection assumed a TFR of 1.93 in 2001 while the current projection assumes a TFR of 1.5 by that year.

Figure 2.2 relates the values of the major demographic variables over the period 1976-2001. It shows the total fertility rate ranging from 1.5 to 2.0, and it shows net migration into the province ranging from 0 to 70,000 per year. These values can be combined to enable us to predict a population as low as 9.2 million and as high as 11.9 million in 2001. Fig. 2.2: p. 1

A total fertility rate of 1.5 combined with zero net migration yields a population of 9.2 million in 2001. This implies an average population growth rate of 0.5 per cent per year to the end of the century. Zero net migration could occur if, for example, the inflow from Quebec falls. In this case, the net foreign immigration would simply offset the outflow to the western provinces.

Total fertility rising to 2.1 in 2001 combined with annual net migration of 70,000 yields a population of 11.9 million in 2001. This implies an average annual rate of population growth of 1.5 per cent. Net migration of 70,000 per year is quite consistent with the levels of the 1950s and 1960s. It could result from higher foreign immigration and/or higher levels of migration into Ontario from other provinces. The TFR of 2.1 is well below the fertility rates of the 1950s and 1960s. This explains why the population growth rate is lower than that of the post-war period.

The Commission's demographic consultant projected the population of Ontario to be between 10.3 and 10.7 million in 2001. For our preferred case we will use a population forecast of 10.55 million in 2001, roughly in the centre of this range. It corresponds to an average annual rate of population growth of 1.0 per cent. This population can occur with various combinations of fertility rates and levels of net migration, as illustrated in Figure 2.2. A TFR of 2.0 and annual net migration of 20,000 or a TFR of 1.5 and annual net migration of 45,000 are two such combinations.

Economic Variables

The traditional method of analysing the long-run growth of an economy is in terms of its productive capacity. The factors that determine the productive capacity of an economy are numerous. They include the number of workers, the skills and training of the workers, the amount of time worked per year, the capital available to assist the workers, and technological change. Studies have been undertaken to determine the contribution of each factor to past growth. None of these studies has been completely successful, but all have found that the increase in the number of workers is by far the largest single factor in determining the growth in productive capacity of an economy.

The traditional method of projecting long-run economic growth is based on this finding. The economic growth rate is calculated from the projected growth of employment and an estimated rate of increase of output per employee. In this approach, the output per employee encompasses the net effect of all of the other factors listed above.

Employment

The working-age population is defined as the population between the ages of 20 and 64. At the present time this group represents about 57 per cent of the total population.

The age structure of Ontario's population is such that the relative size of this group will grow over the next two decades. Depending on the migration and fertility assumptions, the working-age group is

expected to account for 61.5 to 63.5 per cent of Ontario's population in 2001. The working-age population will grow about 0.6 per cent per year faster than the total population. It is projected to include slightly more men than women. But the difference is very small – approximately 50.1 per cent men and 49.9 per cent women.

Labour Force. The labour force consists of people who have paid employment or are actively seeking it. Not everyone in the working-age population has or is seeking paid employment. Some who are younger or older than those in the working-age group are part of the labour force.

The labour force and the working-age population are related by the participation rate. The participation rate expresses the labour force as a percentage of the number of people of working age. There are male and female participation rates, and participation rates for specific age groups. At present, the male participation rate in Canada is about 78 per cent and the female participation rate is about 46 per cent. The male participation rate has been declining gradually, whereas the female participation rate has been rising relatively rapidly. Extrapolation of these historical trends yields a male participation rate of 73 per cent and a female participation rate of 57 per cent by 2000. Similar developments are anticipated for Ontario. The net effect is that the labour force is expected to grow slightly faster than the working-age population.

Unemployment. Only employed workers contribute to the economic output. Hence, the labour force estimates must be divided between those who are employed and those who are unemployed but actively seeking work. The unemployment rate is the percentage of the people in the labour force who are not at present employed and who are seeking work. Current levels of unemployment are high by historic standards. During the mid 1980s the number of people joining the labour force each year will moderate. This should permit a small reduction in the unemployment rate in the long run. The reduction is expected to be between 1 and 2 per cent of the labour force.

Employment Growth in Ontario. The rate of employment growth in Ontario can be calculated from the information provided above. The working-age population is calculated from the population projection. The participation rate is applied, to get the labour force estimate. Employment is calculated by subtracting the unemployed, currently about 6.5 per cent. The results of these calculations are summarized in a table.

Projected population 2001 (millions)	Average population growth (%/year)	Average employment growth (%/year)
9.2	0.5	1.1
10.55	1.0	1.6
11.9	1.5	2.1

Note that, over the entire range of population projections, employment grows 0.6 per cent per year faster than population to 2001. Over half of this extra growth is due to the changing age structure of Ontario's population. It will cause the working-age group to grow more rapidly than the total population. The remainder of the extra growth is due to the higher participation rates and lower unemployment rates.

Other estimates of future participation rates and unemployment rates may differ substantially from those suggested above. Such estimates may reflect different methods of extrapolating historical patterns into the future. Or they may be based on entirely different views of the future. The saturation of consumers' wants has been suggested as a possibility for the future. If this occurred it could lower the participation rates, because people might retire earlier. In either case, it would require large changes in these variables to have an impact on the rate of economic growth. Hence, a detailed review of future participation rates and unemployment rates is not necessary for our purposes.

Productivity

As noted earlier, the output per employee, or gross productivity, embraces the net result of a large number of factors. Several of these factors have opposite effects on the output per worker. Some of the factors can be measured directly and others cannot. The result is that economists have only a limited understanding of the behaviour of this variable.

There has been a continuous decline in the average number of hours worked per year. Reducing the hours worked lowers the output per worker. The hours worked annually can be measured. But it has not

been measured regularly, so only limited data are available. Nevertheless it is expected that the hours of work will continue to fall slowly.

The education and skill of workers have been rising. It is generally felt that this increases output per worker. It is very difficult to measure average levels of education. Relating education levels to worker productivity is even more complicated. Over the next two decades, the educational training of workers will continue to rise.

Generally, the larger the amount of capital equipment per worker, the higher the output per worker. Again no precise relationship exists. Capital investment has been relatively low in Canada during the last few years. This is judged to be one of the major causes of the relatively low growth of output per worker during this period.

Computation of the historic changes in the rate of increase of output per employee in Ontario requires information on the provincial gross domestic product (GDP), the implicit GDP price index for the province, and employment in Ontario. Estimates of the provincial gross domestic product are available from 1961 through 1977.[3] The corresponding price indexes are not reported. Thus, the real provincial GDP must be estimated using either the national GDP price index or the Toronto consumer price index. The calculated rate of growth of real provincial GDP per employee over the period 1961-77 is 1.7 or 1.8 per cent per year depending on the price index used.

It has been argued that productivity growth will be lower in the future. It is asserted that productivity gains are more difficult to realize in service industries than in goods-producing industries. Since service industries are forecast to account for a larger share of total output, a lower rate of productivity growth is expected. The expectation that there will be a degree of saturation of consumer needs also supports this conclusion. Saturation will induce workers to demand more leisure time rather than more income, hence the output per employee will not increase as rapidly as it has in the past.

It has also been argued that productivity growth will be higher in the future. The reduction in the costs of computers will allow them to be used in a great many applications where they are now uneconomic. The result, it is claimed, will be large productivity gains in the service industries as well as in the goods-producing industries. The lower rate of growth of the housing stock and associated municipal infrastructure will mean that less capital is required for these "non-productive" purposes. Since more capital will be available for productive investments, the rate of growth of productivity should rise.

For our preferred projection we will use the historical rate of increase of real GDP per employee in Ontario, which is 1.7 per cent per year.

Growth of Real Gross Domestic Product

The gross domestic product (GDP) is the total production of the economy. The real GDP is the value of the total output adjusted to exclude the effects of inflation. Table 2.1 shows the rate of real GDP growth projected for Ontario to 2000 by the RCEPP and by other groups. With one exception, all of the projections lie between 2.5 and 4.5 per cent per year. Most of the projections lie in the upper part of the range. Our preferred projection anticipates real economic growth of 3.3 per cent per year to 2000.

Conservation

Economic Growth and Energy Growth

There is considerable evidence of a strong and close relationship between economic growth and energy growth. Figure 2.3 shows the relationship between income and energy consumption for a number of countries. It is evident from the figure that energy consumption rises as income increases. Fig. 2.3: p. 18

Evidence of this close relationship between economic growth and energy growth is also found in historical data. The RCEPP's *Interim Report* shows this in its Figure 2.3. Ontario's real domestic product grew at an average rate of 5.1 per cent per year from 1959 through 1975. Over the same period, the consumption of secondary energy – the energy delivered to consumers – grew at an average annual rate of 4.0 per cent. Primary energy consumption – the total amount of energy used in the province – grew at a slightly higher rate.

Can energy growth and economic growth be de-coupled? Some of the abundant evidence of the close link between the two has been cited. There is also evidence that this relationship is not as close as it appears at first glance. Wide variations are found in the energy consumption of countries and regions with similar incomes. This can be seen in Figure 2.3. The same pattern was noted in the *Interim Report*

Table 2.1 Comparison of Projections of Economic Growth in Ontario and Canada to 2000[a]

Projection	Source	Population	Employment	Output per worker	Real economic output[b]
			(average annual rate of growth–%)		
Ontario					
Royal Commission on Electric Power Planning (1975-2000)	1				
Reference		1.0	1.6	1.9	3.5
Low		0.5	1.1	1.4	2.5
High		1.5	2.1	2.4	4.5
Ontario Hydro (1980-2000)	2				
Probable			1.3	2.3	3.6
Low			1.3	1.4	2.7
Ministries of Energy and Treasury and Economics (1976-2000)	3	1.2			4.3
SRI/CEA Model (Leonard & Associates' forecast)(1976-2000)	4	1.3	2.1	1.4	3.5
Data Resources Inc. (1976-95)	5	–	2.6	1.4	4.0
Canada					
National Energy Board (1976-95)	6	1.1	1.8	2.2	4.0
Energy, Mines and Resources Canada (1975-90)	7	1.3	2.1	1.9	4.0
This is the "Low Growth" or preferred case					
Institute for Research on Public Policy (1975-2000)	8	1.1	1.5–2.0	1.5–2.0	3.5
Statistics Canada Long-term Simulation Model (1975-2000)	9				
Case A		0.9	1.5	0.7	2.25
Case B		0.9	1.5	1.8	3.25
Case C		0.9	1.5	2.0	3.5

Notes:

a) The correct method of calculating the rate of growth of real GDP from the rates of growth of employment and output per worker is by multiplication. The rate of 1.6% is written 1.016 and the rate of 1.9% is written 1.019. These factors are multiplied to get 1.0353, for 3.53%, as the rate of growth of real GDP. As long as the growth rates involved are small (less than 4%) the result can be approximated by adding the percentages, i.e., 1.6% + 1.9% = 3.5%.

b) "Economic output" covers different measures used by researchers, such as GDP, GNP, GPP, and "output". The slight variations among these measures are insignificant for our purposes.

Sources:

1. RCEPP projections.
2. Ontario Hydro Load Forecast Report 790212, February 1979.
3. Ontario Energy Review, Ministry of Energy, June 1979.
4. "Long-range Electricity Forecast for Canada – Methodology", SRI International November 1978 (calculated from Table B-8).
5. "Overview and Economic Outlook", Ontario Hydro presentation to Select Committee on Hydro Affairs, Exhibit No. D-79, February 27, 1979.
6. "Canadian Oil Supply and Requirements", National Energy Board, Ottawa, September 1978.
7. "Energy Demand Projections – a Total Energy Approach", Report ER-77-74, Energy Policy Analysis Division, Department of Energy, Mines and Resources, Ottawa, June 1977.
8. "Canadian Energy: The Next Twenty Years and Beyond" by R. Clayton et al, Institute for Research on Public Policy, Montreal, 1978.
9. "Energy Futures: Scenarios and Postulations" by S.F. Gribble and K.E. Hamilton, Structural Analysis Division, Statistics Canada, Ottawa, 1977.

(Figure 2.1). Figure 2.3 of the *Interim Report* suggests that the historic relationship between energy and economic growth in Ontario may have started to change during the early 1970s. The relationship between energy growth and economic growth can be changed.

Measuring Conservation

The relationship of energy consumption to economic output is commonly used as the measure of energy intensity. Change in energy intensity is usually measured in one of two ways:

- The current level of energy consumption per dollar of GDP is taken as a base. Conservation can then be measured in terms of the percentage reduction in energy consumption per dollar of real GDP over a specified period. For example, the current level of energy consumption per dollar of GDP can be given an index value of 100. A 30 per cent reduction in energy intensity over 25 years would reduce the index to 70 over this period. The problem with this measure is that it is not

independent of time. A 30 per cent conservation effort over 10 years is very different from the same reduction over 25 years.

- The ratio of the rate of growth of energy consumption to the rate of real economic growth can be used as an aggregate measure of conservation. This is the method used in the *Interim Report*. The medium ratio of 0.48 was applied to the medium economic growth rate of 4.0 per cent per year to give the end-use energy growth rate of 1.92 per cent per annum. This measure yields a different conservation effect for each economic growth rate. The conservation effect is different for a value of 0.48 and an economic growth rate of 3.0 per cent than it is when the economic growth rate is 6.0 per cent per year.

We have found it convenient to adopt a different measure of change in energy intensity in this report. The measure used here is the difference between the rate of real economic growth and the rate of energy growth. Using the figures of the *Interim Report*, the rate of change of energy intensity is (4.0 – 1.92) = 2.08 per cent per year.[4] This definition is easier to work with than the ratio of the two growth rates. And a given rate of change of energy intensity, such as 2.0 per cent per year, represents the same rate of energy saving regardless of the economic growth rate.

Our new measure is a close approximation to the percentage reduction measure except that it is expressed differently. The percentage reduction measure reports the cumulative effect over a specified time period. Our measure expresses the same change as an average annual effect.

Consider as an example an economy with a real economic growth rate of 4.0 per cent per year and an annual energy growth rate of 2.0 per cent. The initial energy consumption per dollar of GDP is given an index value of 100. Over 25 years the real economic output grows by a factor of 2.666 (4.0 per cent compounded for 25 years). The energy consumed grows by a factor of 1.641. At the end of the period the energy consumed per dollar of GDP has an index value of $(1.641/2.666) \times 100 = 61.5$. The energy intensity has been reduced by 38.5 per cent over 25 years. A cumulative reduction of 38.5 per cent over 25 years is equivalent to an average annual reduction of 1.96 per cent. Our method of subtracting the two annual growth rates (4.0 – 2.0 = 2.0) gives a very close approximation to this figure.[5]

The Effects of Energy Intensity

Reduction in energy intensity is very broadly defined. It is anything that reduces the energy consumed per dollar of real GDP. This definition allows us to distinguish these two types of effects:

- reduced use of energy for any given production or consumption activity
- shifts from more (less) energy-intensive production or consumption to less (more) energy-intensive patterns

The first effect will be termed energy efficiency, or conservation, and the second will be called structural change. It is important to note that structural changes may increase or decrease energy intensity.

Energy efficiency corresponds to the popular concept of conservation. It includes all steps to reduce energy waste and all efforts that reduce the energy required to produce a given output. Examples include better insulation of buildings, improved fuel efficiency of automobiles, and the burning by the pulp and paper industry of its own wastes.

Structural change does not require specific policies, yet it can lead to a significant reduction or increase in energy consumption. The change in the age structure of Ontario's population has contributed to a rapid growth of the housing stock and the automobile fleet. Energy consumption has grown accordingly. In the future, the age structure of the population will lead to much slower expansion of the housing and automobile stocks. The rates of growth of these components of energy demand are therefore likely to be lower than in the past.

In practice it is difficult to define energy efficiency and structural change effects precisely, hence they cannot be measured. How is a shift from automobile travel to light-rail transit classified? It represents a change from more to less energy-intensive consumption patterns and so could be considered a structural change. The light-rail transit vehicles may be more efficient than the existing public transit vehicles, so it could also be considered a conservation effect.

Real GDP is a measure of the total income as well as of the total output of the economy. Structural change, then, can also be viewed in terms of shifts from more to less energy-intensive consumption patterns, or vice versa. Such changes in consumption patterns may occur for reasons totally unrelated to conservation. A switch from water-skiing to sailing or from ski-dooing to cross-country skiing would have the effect of reducing the energy intensity of consumption patterns.

Implicit in the foregoing examples is the premise that the changes in consumption patterns are voluntary. Concern that involuntary changes in life-style will be required in order to reduce energy consumption was expressed to the Commission. This concern will be addressed below.

The possibility that saturation of consumers' wants will occur has been suggested. A person's ability and/or desire to consume goods and services produced by others is felt to be limited. As this limit is approached, the person's rate of increase of consumption slackens and gradually falls to zero. At that point all of his wants are satisfied and saturation has occurred. Saturation would, therefore, limit the consumer's energy demands.

Saturation would probably lead to slower economic growth – smaller increases in per capita income. If per capita income (real GDP) continues to grow, consumers must dispose of their added income in one way or another. Since the consumer has everything he wants, he can spend only a limited amount on goods and services. He will spend enough to maintain his existing consumption pattern. The rest must be saved, hoarded, or given away. More realistically, consumers, when they reach saturation, would choose to limit the growth of their real income. They would reduce the time they work rather than raise their incomes. This would lead to a lower rate of growth of output per employee and hence to a lower rate of economic growth.

Conservation and Energy Supply

In the development of energy policy, reducing the energy intensity must be considered as an alternative to increasing energy supplies. A reduction in the energy intensity is an estimate of the extent to which energy demand has been reduced.

Consider, as an example, a situation where the energy intensity is forecast to fall at a rate of 1 per cent per year and energy demand is forecast to grow at a rate of 2.5 per cent per year, given existing policies. A rate of reduction of energy intensity of 1.5 per cent per year would reduce the required rate of growth of energy supplies to 2.0 per cent per year.

A reduction of 0.5 per cent in the rate of growth of energy demand allows much larger reductions in the rate of growth of demand for individual forms of energy. To illustrate, assume that the energy in our example is supplied as follows: oil – 40 per cent, natural gas – 30 per cent, and electricity – 30 per cent. Then a 2.5 per cent per year growth in demand could be supplied by having the three energy forms grow at the following rates: oil – 1.5 per cent per year, natural gas – 2.5 per cent per year, and electricity – 3.9 per cent per year. Reducing the rate of growth of total energy demand from 2.5 to 2.0 per cent per year allows the rate of growth of demand for oil to be reduced from 1.5 to 0.0 per cent per year, assuming no change in the growth rates for the other other energy forms.

Reducing the energy intensity of an economy cannot be accomplished without incurring costs. Reducing the energy required for space heating requires investment in insulation. Improving their fuel efficiency has contributed to higher prices for automobiles. The cost of greater energy efficiency is, in some cases, very small. New homes and commercial buildings that require only 20 per cent of the energy of their conventional counterparts for space heating can be built at costs competitive with those for conventional buildings.

Generally, the measures best suited to reducing the energy intensity are conservation policies. These policies work to increase the efficiency with which energy is used in various applications. Policies to encourage changes in the structure of society and hence indirectly reduce the energy intensity are much less efficient.

The development of energy policy, then, involves a consideration of possible conservation measures and alternative sources of supply. Each conservation measure has a different potential energy saving and an associated cost. Likewise, each source of supply has a different potential to supply energy and an associated cost. In principle, there is a least-cost set of policies that includes the conservation measures and sources of supply with the lowest cost per joule of energy saved or supplied and which meet the forecast demand. In practice, this least-cost alternative may not supply the required mix of energy forms. Substitution programmes or changes in the mix of conservation and supply measures will ensure the proper mix of energy forms. The least-cost set of energy policies will continue to include both conservation measures and supply measures.

Aggregate Energy Efficiency

A detailed review of possible methods of improving the efficiency of energy use is beyond the scope of this paper, but a brief overview of the subject will be given.

Figure 2.4 is a flow diagram of the conversion of energy by the economy. One hundred units of primary energy are shown entering the Ontario economy at the bottom of the figure. According to the first law of thermodynamics, energy cannot be destroyed. So the 100 units of energy are returned to the biosphere. In passing through the economy, the energy is converted from its high-quality, concentrated form – coal, oil, uranium, etc. – to low-quality, diluted forms – warm air and water. It must be stressed that the data in Figure 2.4 are approximate. Detailed energy statistics are not available in this form; rather, the data must be estimated from a number of disparate sources and reconciled. Fig. 2.4: p. 19

The figure shows the supplies of concentrated energy forms – coal, oil, natural gas, uranium, etc. – entering the Ontario economy. In the processes of converting the energy into forms that can be used, delivering it to the points of use, and using it for productive purposes, almost 75 per cent of the total is lost as warm air and water. The first losses occur in the energy supply systems. These are the systems that move energy from the point of origin to the point of use and convert it to the appropriate form. The energy supply systems include the generation and transmission of electricity, shipment of oil and natural gas by pipeline, refining of crude oil, etc. Some 31.7 per cent of the energy used by the province is lost in the energy supply systems.

Additional losses occur when the energy is used. These losses amount to 41.4 per cent of the total energy used in the province. Overall, about 40 per cent of the energy delivered to the points of use results in useful work; the rest is dissipated as warm air or water. The efficiency of energy use in the residential and commercial, industrial, and transportation sectors is shown separately in the figure.

Most of the energy losses that occur in the energy supply systems are due to the generation and transmission of electricity. The electricity supply system receives 31.6 units of energy, and it produces 9.2 units of energy in the form of electricity. Some 22.4 units of energy, or 70.9 per cent of the energy required by the electricity supply system, are dissipated. Furthermore, the 22.4 units represent 22.4 per cent of the energy used in Ontario.

The supply systems for energy forms other than electricity are much more efficient. They deliver 86 per cent of the energy they receive to the point of use in a form in which it can be used.

The efficiency of energy use varies markedly from one economic sector to the next. The transportation sector, whose energy demands are dominated by the automobile, is the least efficient user of energy. The internal combustion engine converts thermal energy (gasoline) to motive energy, a process that entails large energy losses in the form of heat. Additional losses occur in the conversion of the motive energy to movement over the road. Only about 12 per cent of the energy used by the transportation sector results in useful work. The corresponding figures for the residential and commercial sector and the industrial sector are 40 and 56 per cent respectively. However, the amount of "useful work" can be increased by expanding the efficiency of the end-use devices.

Only 26.7 per cent of the energy used in Ontario is consumed in the performance of useful work. The rest is dispersed as waste heat. Energy supply processes, principally the generation of electricity, dissipate just over 30 per cent of the energy used in the province. The remainder is dissipated in various end-use applications. The energy dispersed by the transportation, industrial, and residential and commercial sectors is divided roughly equally among them, but the efficiency of energy use is lowest by far in the transportation sector.

Conservation and Life-style

The term "life-style" must be defined in a manner that can be related to conservation efforts. We will consider life-style to consist of consumption patterns – all consumer goods and services – plus working conditions. Consumer goods and services will include government services, such as police protection; and institutional services, such as education. Working conditions include space conditioning, lighting, tools, and equipment.

Conservation activities can now be classified in terms of their impact on life-style. This yields the following classification:

- Reduction of energy waste. It is possible to achieve a significant reduction in energy waste with little impact on life-styles. Lights can be switched off when they are not needed. Industrial waste

heat can be used for co-generation, district heating, or other processes. Time-of-day thermostats can be installed. Elimination of the needless waste of any product will save energy, since the manufacture of every product requires energy.

- Redesigning of goods and services to make them more energy-efficient without affecting their consumption characteristics. Buildings can be designed and built to use considerably less energy, without adversely affecting the inhabitants. The fuel efficiency of automobiles can be improved. Appliances can be made more efficient. Non-thermal wastes can be used as fuels. Metals, paper, and other materials can be recycled. Goods can be shipped by rail rather than truck, and so less energy will be required for their transportation.
- Elimination of "frills" that have little impact on the consumption characteristics of the products. To achieve this, we could use less illuminated advertising; lower the standards of lighting for buildings, stadiums, and streets; reduce the sizes of cars and buildings; increase the useful life of durable products; and eliminate frills such as electric seat adjustment in automobiles.

All of these actions can conserve energy without significantly affecting life-styles. There are a number of other types of conservation activities that might be judged by some as adversely affecting life-styles. Such activities include:

- Limiting the use of specific energy-intensive goods and services. Policies to limit the use of items such as snowmobiles, motor boats, saunas, air conditioners, and private swimming pools might be introduced to conserve energy. Such policies would be judged by many as adversely affecting their life-styles. Provision of attractive, less energy-intensive alternatives might make these policies more palatable.
- Restrictions on the introduction of new goods and services, which tend to add to energy consumption. A new refrigerator often does not replace the old one – both are used where one was adequate before. The acquisition of snowmobiles could be limited to persons who can demonstrate a need for such a vehicle.
- Changes in life-style patterns to conserve energy. Such changes might include: increased use of public transportation, greater use of communications rather than travel, the restructuring of urban areas to minimize travel, the elimination of escalators and moving sidewalks, and the use of lower ambient temperatures in winter and higher ambient temperatures in summer in buildings. Some people might welcome changes along these lines as representing a healthier life-style.

In summary, large reductions in energy consumption are possible with no change in life-styles. A number of measures to reduce energy consumption would affect life-styles; the changes in life-style would be judged to be desirable by some and undesirable by others.

Saturation

Some forecasts indicate that Canadian consumers may approach saturation of their wants during the next 20 years. The Statistics Canada long-term simulation model was used to assess the effects of saturation on energy consumption in Canada. The study compares a base case and a consumption saturation case. The results are shown in Table 2.2.

Table 2.2 Projected Effects of Consumption Saturation on Energy Demand in Canada, 1975–2000 (rates of growth)

	Base case (%/year)	Consumption saturation (%/year)
Population	1.2	1.2
Employment	2.4	2.4
Hours worked per year	0	−1.4
Productivity per hour worked	1.2	1.2
Real GDP	3.6	2.2
Per capita real GDP	2.4	0.9
Energy intensity reduction	1.6	1.1
Total end-use energy	2.0	1.1
Oil	1.6	0.7
Natural gas	2.2	1.4
Coal	1.8	0.6
Electricity	3.0	2.3

Source: Based on a study by B.C. McInnis, Statistics Canada, June 21, 1979.

The base case projects real economic growth of 3.5 per cent per year to 2000. Most of this growth is used

to raise per capita real incomes. Consumption levels show a corresponding increase. Spending on some goods moderates while that on other goods continues to rise. There is also a small reduction in the length of the work year.

The consumption saturation case yields a lower rate of real growth – 2.15 per cent per year. Most of the productivity growth is absorbed by reductions in the work year to 45 weeks of 30 hours each. There is some increase in per capita real incomes. Consumer spending on most goods and services moderates.

Consumption saturation lowers the rate of growth of energy demand, but not by much. It also lowers the impact of conservation because there is less replacement of inefficient appliances, automobiles, industrial equipment, etc. The net effect, then, is to reduce the rate of growth of energy demand from 2.0 to 1.8 per cent per year. Consumption saturation also lowers the rate of growth of demand for each of the individual energy forms.

Specific Conservation Measures

A number of specific conservation measures that can be implemented by 2000 are outlined below. Detailed discussion of these measures appears in the volume dealing with supply. The purpose here is simply to give an indication of the impact of these measures on energy demand to 2000.

Residential Sector

- *Space Heating* – New housing units, other than apartments, are forecast to use only 35 per cent as much energy for space heating as existing units. Existing housing units, other than apartments, are expected to reduce their space heating needs by 30 per cent as a result of improved insulation. The space heating needs of apartments are not expected to change significantly.
- *Water Heating* – Increased insulation of hot water tanks and greater use of point-of-use heating could reduce energy demand by 20 per cent per household by 2000.
- *Appliances* – Despite increased penetration of most appliances, raising efficiencies to the U.S. Federal Energy Administration (USFEA) 1980 standards could reduce the average energy demand for appliances by 10 to 15 per cent per household by 2000.

The overall effect is a rate of growth of energy demand in the residential sector that is 1.6 per cent per year less than it otherwise would be.

Commercial Sector

Retrofit and conservation measures could reduce the present energy consumption in commercial buildings by 20 per cent per square metre per year by 2000. New commercial buildings require only two-thirds as much energy per square metre per year as existing buildings. New energy-conserving commercial buildings can operate with less than 40 per cent of the energy per square metre per year required for existing buildings. Half of the new commercial space could be in energy-conserving buildings by 2000.

The overall effect is a rate of growth of energy demand in the commercial sector that is 1.5 per cent per year less than it otherwise would be.

Industrial Sector

- *Motive Power* – Changes in the technology of electric motors and better matching of motor size to average load could raise the efficiency of motor operation from 52 to 75 per cent by 2000.
- *Process Steam and Direct Heat* – The use of more continuous processes, waste heat recovery, and co-generation could reduce energy consumption per unit of output by 25 per cent by 2000.
- *Space Heating* – Improvements in insulation, lower heating and higher cooling temperatures, and the use of waste process heat for space heating could reduce space heating needs by 75 per cent.

The overall effect is a rate of growth of energy demand in the industrial sector that is 1.2 per cent per year less than it otherwise would be.

Transportation Sector

- *Passengers* – The 1985 legislated fleet mileage standards for automobiles will apply to all automobiles in operation by 2000. This will reduce the energy consumption per passenger mile by half. There could be a shift to more energy-efficient public transportation. Together, these changes could reduce the energy demand for passenger transportation by 50 per cent.

- *Goods* – Improvements in the energy efficiency of trucks, higher utilization levels of vehicles, and shifts to water and rail transport could reduce the energy demand for goods transportation by 25 per cent.

The overall effect is a rate of growth of energy demand in the transportation sector that is 2.1 per cent per year less than it otherwise would be.

Summary

The four end-use sectors discussed make up different shares of the total energy demand. When each sector is weighted by its share of the total demand, the reduction in the rate of growth of energy demand is approximately 1.55 per cent per year less then it otherwise would be.

Summary

The rate of population growth depends on mortality rates, fertility rates, and net migration. Mortality rates are quite stable, so the last two components become the key determinants of population growth. Fertility rates have been declining for 15 years. They are expected to remain below the long-run natural replacement level until the end of the century. Ontario's share of immigrants is declining and the net number of people arriving from other provinces is shrinking. The population of Ontario in 2001 is forecast at 10.55 million, which implies a rate of growth of 1 per cent per year.

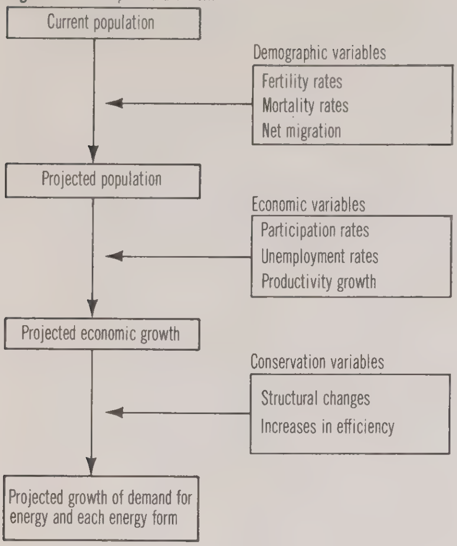
The age structure of the population is such that the labour force will grow faster than the population. Employment is projected to grow at an average annual rate of 1.6 per cent. The historic rate of increase of productivity in Ontario is 1.7 per cent per year. No compelling reason is found to project higher or lower rates of productivity growth in the future. The real domestic product of Ontario is therefore projected to grow at an average annual rate of 3.3 per cent to the year 2000.

Energy intensity, which includes both efficiency improvements and changes in the structure of society, is measured as the difference between the annual rate of growth of real gross domestic product and the annual rate of growth of energy demand. A number of specific conservation measures that are likely to be implemented before 2000 are identified. Together, these measures are expected to reduce the growth in demand for energy below what it would otherwise be by 1.55 per cent per year. The preferred projection of the rate of growth of demand for energy in Ontario to 2000 is 1.75 per cent per year.

Large reductions in energy consumption are possible with no change in life-styles. A number of the measures that could be taken to reduce energy consumption would affect life-styles; and these changes would not please everybody.

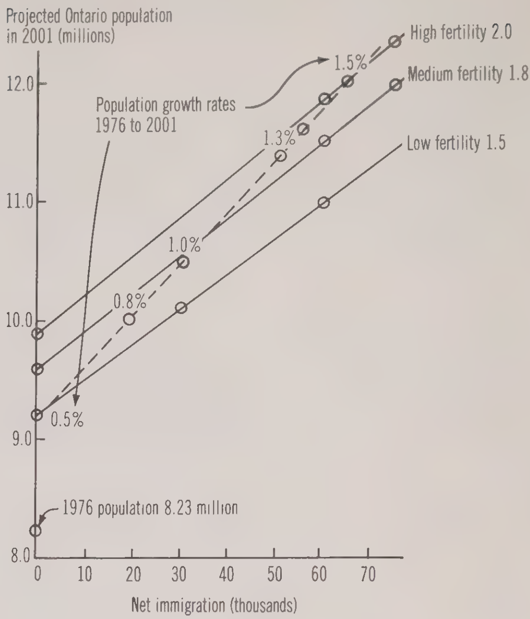
The impact of a saturation of consumers' wants was analysed by Statistics Canada. Saturation yields a lower rate of real economic growth. It also lowers the rate of growth of energy demand, but not by much.

Figure 2.1 Conceptual Framework



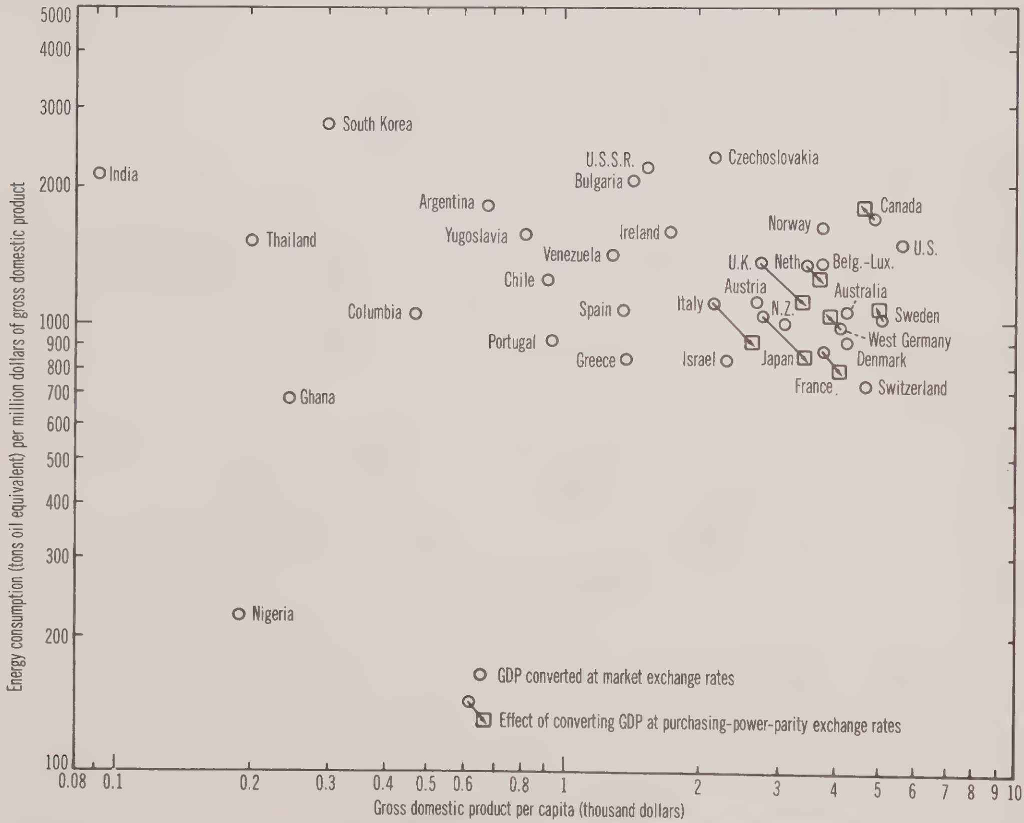
Source: RCEPP.

Figure 2.2 Range of Population Growth Assumptions to 2001, Ontario



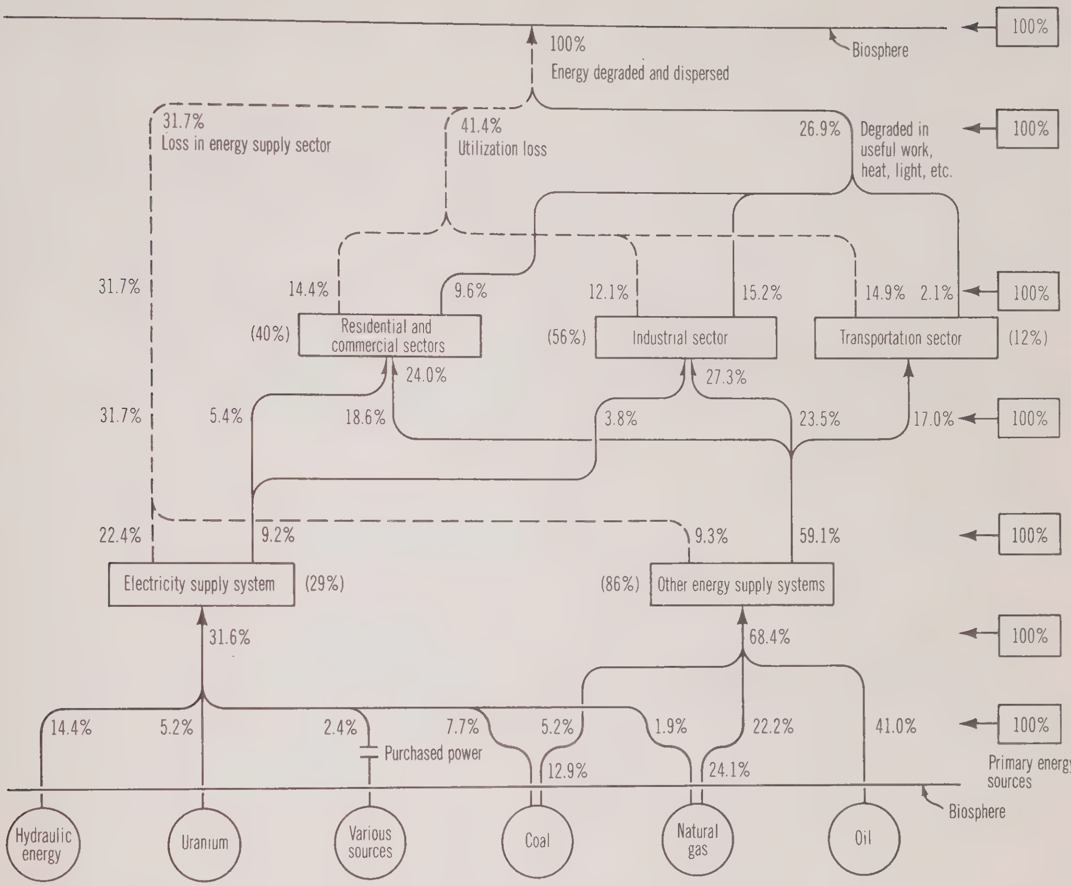
Source: RCEPP.

Figure 2.3 Energy/Output Ratios versus National Output per Capita for Selected Countries, 1972



Source: "How Industrial Societies Use Energy" by J. Darmstadter, J. Dunkerley, and J. Alterman. Baltimore: The Johns Hopkins University Press, 1977.

Figure 2.4 Ontario's Energy Flow—1973-74 (an approximation for illustrative purposes only)



Note: Figures in brackets give the energy conversion efficiency.

Source: RCEPP.

CHAPTER THREE

Ontario Hydro's Load-Forecasting Process

Ontario Hydro must forecast the demand for electricity in order to plan the new facilities it needs. Its forecast needs are complex:

- The demand forecast is used for facilities planning. Since electric energy cannot readily be stored, the facilities are planned to meet the peak demand. The load forecast, therefore, is concerned with the demand during the peak 20-minute period.
- Ontario Hydro's facilities serve different areas. Some transformer stations serve only part of a township. Some generating plants serve a large number of counties. To determine where new facilities will be needed and what will be required of them, the load forecast must be disaggregated into a set of consistent forecasts for a large number of small geographic areas.

As will be shown below, Ontario Hydro's load-forecasting record has been very good, until recently. The upheaval in the world oil market during the last five years has affected the demand for all forms of energy in Ontario. This makes it more difficult now than it was in the past to forecast the demand for electricity.

Terminology

Ontario Hydro uses a number of terms in the context of demand forecasting that may have different meanings elsewhere. These terms are explained below.

Energy

Energy is the amount of electricity delivered from one part of the system to another. Energy is generated and then it is delivered to the transmission system. From the transmission system it is delivered to customers. The amount of energy delivered is the rate of delivery times the duration. The rate is measured in watts. The standard duration is one hour, so the energy delivered is measured in watt hours. A kilowatt hour is 1,000 W·h, a megawatt hour is 1,000 kW·h, and a gigawatt hour is 1,000 MW·h. Energy measured at the point of generation is called primary energy.[1] Energy measured at the point of delivery to customers is called energy demand. Ontario Hydro's primary energy for 1978 was 95,372 GW·h.

Rate of Delivery

The rate of delivery is measured in watts. The rate fluctuates constantly with time. Ontario Hydro measures the rate of delivery by taking the average rate over each 20-minute period. In this way it measures 72 rates of delivery in a day.

Peak

The peak for a day is the largest of the 20-minute averages. The peak for a month is the largest of the 20-minute averages in the month. The peak for a year is the largest of the 20-minute averages in the year. These are referred to as the daily, monthly, and annual peaks.

The peak at the point of generation is called the primary peak. The peak at the point of delivery to customers is called the peak demand. The Ontario Hydro primary peak was 16,371 MW in 1978.

Transmission Loss

To transmit electric energy requires energy. The amount of energy required depends on the voltage, the time of year (conductor temperature), the rate of delivery, and the distance transmitted. Consequently there is a difference between the amount of energy that customers need and the amount the system must generate. The difference between the primary energy and the energy demand is the transmission loss.

Load Factor

The load factor is the ratio of the average amount of energy delivered during a given period to the peak delivered in the same period. The daily load factor is the ratio of the average amount of energy delivered during the 72 20-minute periods to the energy delivered during the peak period for the day. Load factor is usually expressed as a percentage. Typical load factors for Ontario Hydro are:

annual: 65-70 per cent
monthly: 75-80 per cent
daily: 85-90 per cent

In 1978 the annual load factor was 66.5 per cent.[2]

Reliability

The total installed capacity cannot always be available. Facilities have to be shut down for scheduled or unscheduled maintenance. In thermal stations there may be fuel and icing problems. Shortages of water occur in hydraulic stations. Electrical storms can disrupt transmission. Reliability provision is the amount of extra generation and distribution capacity that is needed to allow for equipment shutdowns without substantially reducing the probability that the peak demand can be met.

Many of the events that cause facilities to be unavailable are random occurrences. It is possible to predict that such events *will* happen, but not *when* they will happen. Provision for system reliability simply increases the likelihood that the system will be able to meet the peak demand. It cannot guarantee that the system will be able to meet the peak demand. Currently, generating capacity equal to 25 per cent of the primary peak is provided for system reliability.

Surplus Capacity

Surplus generating capacity exists when the installed capacity is greater than the total of the primary peak and the reliability provision. Surplus capacity is not necessarily redundant. The surplus increases the probability of meeting peak demand. In December 1976, for instance, a nuclear reactor was out of service for maintenance, the coal pile at Nanticoke froze, and a cold day occurred. In that case the surplus capacity of Ontario Hydro enabled it to avoid a power shortage. Surplus capacity also permits more economical scheduling of maintenance work; equipment suffering forced outages need not always be repaired on an emergency basis. In 1978, Ontario Hydro had surplus capacity equivalent to 17 per cent of the primary peak.

Coincidence Factor and Diversity Factor

Each customer has an annual peak demand. The customer's peak will depend on his location and his use of electricity. The coincidence factor relates the customer's peak demand to his demand at the time of system peak. For instance, a customer may have an annual peak demand of 500 kW but a demand of only 450 kW when the system peak occurs. The coincidence factor for that customer would be 450/500. This factor enables disaggregated peaks to be aggregated into a coincident peak. The diversity factor is 1/(coincidence factor). Great diversity in the system indicates that peak loads will occur at very different times and that many loads will be below their peak at the time of the system peak. As diversity increases, so does the load factor.

Ontario Hydro's Load-Forecasting Procedure

This section describes the load-forecasting procedure that was used by Ontario Hydro to prepare its 1979 load forecast.

Purpose

The load forecast is one of the prime inputs to Ontario Hydro's planning process. It indicates the demand for electric energy that Hydro will have to face at various times in the future. If these future demands are to be met, a wide variety of actions must be initiated far in advance.

Planning is required in the broad areas of physical facilities, technological development, purchase contracts, financial resources, and personnel if future electricity demands are to be met. The load forecast is a direct or indirect input to all of these planning processes, but it is primarily directed towards planning the physical system – generating plants, transmission lines, and transformer stations.

The load forecast focuses on the annual peak, because this is found to be more stable than total energy. Also, the design of the physical system is determined in part by the need to meet the peak demand. The load shape is important, in the selection of the mix of facilities.

The forecast period is also largely determined by the planning needs of the physical system. Ontario Hydro estimates that, at present, 10 to 14 years elapse between the date of a decision to proceed with a generating plant and the date when the plant becomes operational. This period is getting longer. Somewhat shorter periods are needed for local distribution facilities. The peak demand is converted, by means of the load factor, into an energy demand forecast. This is one of the inputs into the planning of fuel purchases.

Geographical Subdivisions

The components of the physical system serve specific geographical areas. To plan the physical system it is necessary to forecast the demand for electric energy in each of the relevant geographical areas.

Fig. 3.1: p. 30

The existing system determines, to a large extent, the geographical areas for which forecasts are required. The structure and customer hierarchy of the existing system are shown in Figure 3.1.

Ontario Hydro operates an east system and a west system. The east system (95 per cent of the load) comprises approximately the area east of Wawa. The west system covers the balance of the province. The reason for this division is the large, sparsely populated area between the two systems.

The next subdivision is into regions. There are seven regions in the total system, as follows:

Northwest region – West System
Central region – East System
Niagara region – East System
Western region – East System
Eastern region – East System
Georgian Bay region – East System
Northeastern region – East System

The load in each region is subdivided into three categories of customers: Municipal customers buy wholesale power and distribute it to individual customers; Toronto Hydro is one of the large municipal customers. Retail customers are farm, cottage property, and industrial customers whose annual demand is less than 5,000 kW and who are not in an area served by a local public utility. Direct industrial customers have a demand of 5,000 kW or more each year.

The customers' loads are further subdivided into geographical areas which roughly coincide with local distribution facilities. There are currently 59 local distribution areas, as well as an overall "area" comprising lakefront customers.

The Forecasting Procedure — Overview

Fig. 3.2: p. 30

The procedure used for the 1979 load forecast is shown in Figure 3.2. The numbers used in the following sections refer to the steps identified in the figure.

There are four parts to the procedure:

- medium-range forecast – prefix 1
- long-range forecast – prefix 2
- small-area and class-of-customer forecast – prefix 3
- end-use forecast – prefix 4.

(The end-use forecast is shown in dotted lines because it is under development and was not used in 1979.)

The rectangles in the figure indicate a model, a set of data, or a forecast. The circles indicate points where judgement is exercised in conjunction with analysis or when differing data or forecasts are combined and reconciled.

Medium-Range Forecast

The municipal and direct industrial customers (1.1) were asked in October 1978 to estimate their peak demand, by month, for the next two years (1979, 1980), and their December peak for the following four years (1981-4). These forecasts were scrutinized by Ontario Hydro regional marketing staff and assembled into the regional estimates of peak demand.

Two adjustments are needed to convert these estimates to coincident primary system demand. The sum of customer estimates is not necessarily a coincident sum. The application of diversity factors converts the estimates to coincidence with the system peak at the demand point. The second adjustment concerns the transmission losses. These must be added to the demand point estimates to get the regional estimate of primary peak for the system (1.4). In practice it is found that the corrections for diversity and losses just about balance each other.

An econometric model is also used to generate a medium-range forecast of primary system peak (1.5). This model is discussed in detail in Appendix A.

The model requires a variety of inputs whose values are forecast by other groups:

- Ontario Employment – Economics Division, Ontario Hydro
- Productivity – Economics Division, Ontario Hydro
- Oil Price – Ministry of Energy
- Gas Price – Ministry of Energy
- Peak Charge – Ontario Hydro financial planning model
- Energy Wholesale Rate – Ontario Hydro financial planning model

The regional estimates and the model forecast are compared. A great deal of judgement must be exercised in reconciling the two forecasts. The final product is the 1979 medium-range forecast of primary system peak (1.8).

Unallocated load is introduced at this point (1.9). It is the difference between the 1979 forecast and the sum of the regional estimates. The 1979 forecast of primary peak was less than the sum of regional estimates. Hence, the unallocated load was negative. This indicates that, in total, the regional estimates were judged to be too high. The considerations that entered into the regional estimates and the model forecast were reported in Ontario Hydro's "Load Forecast 1979":[3]

1. The starting point of the regional estimates appeared to be too high as indicated by a forecast growth of 8 per cent in 1979.
2. The high rates of growth indicated by the model in 1982-4 depend critically upon the timing and magnitude of an increase in economic activity. There is considerable uncertainty about both timing and magnitude.
3. The very low rates of growth shown by the model reflect large real price increases and a very weak economy.
4. A similar model for January demands reveals considerably less discrepancy under identical assumptions about the external and pricing environment.

Long-Range Forecast

The long-range system forecast covers the period to 2000 (2.3). The forecast is based on the economic projections, historical data, and the medium-range forecast. The long-range forecast is expressed as an average annual growth rate for each of four five-year periods. Within each period, the growth rate is taken to be constant.

The 1979 long-range forecast is:

1980-85: 5.0% annual growth rate
1985-90: 4.9% annual growth rate
1990-95: 4.5% annual growth rate
1995-2000: 4.0% annual growth rate

Source: *Potential Long Term Growth of Demand in the East System*. Toronto: Ontario Hydro, February 1979, p.6.

The long-range forecast gives coincident primary peak demand of the total system. The system load factor is forecast and applied to the forecast peak to give the total system primary energy forecast. Historical data on hourly energy are used to forecast "load shapes". These are the profiles of weekly and monthly load for each period of the long-range forecast (2.5).

Small-Area and Class-of-Customer Forecasts

This is a long-range forecast of peak and energy demand to 2000 broken down by systems, by class of customer, by area, and by municipal customer.

The disaggregation starts with the long-range system forecast. Transmission losses are estimated on the basis of historical experience. Subtracting these from the primary peak and adjusting for the

unallocated load gives the peak demand. Diversity factors are also estimated from historical experience. These are applied to the peak demand to get the sum of customer peak demands (3.9). This will be higher than the peak demand because the customer peaks do not all occur simultaneously. The transmission losses and diversity approximately balance each other, so the sum of the customer peaks is approximately equal to the primary peak.

The historical customer load factor is used to obtain the forecast of customer energy demand from the customer peak demand.

The total unallocated load is distributed across the seven regions to produce the preliminary forecast of peak and energy demand by region. Double exponential smoothing of historical regional load growth is used, together with regional comments and specific new (or abandoned) loads, to get the final long-term regional forecast (3.3).[4]

A similar procedure is used to get regional forecasts by class of customer (3.5). The judgements, in this case, take account of changes in industry structure and urban growth.

The regional estimates for each class of customer are further divided into the areas that make up each region (3.7). This requires that the unallocated load be distributed to classes of customer. At this point, the area forecasts of peak and energy demand are reconciled with the corresponding customer forecasts.

End-Use Forecasts

End uses give the purposes for which electrical energy is used – lighting, electric motors, street lighting, electric space heating, water heating, appliances, office machines, electrolytic industrial processes, etc. If the demand for each end use can be forecast, then the demand for electric energy can be calculated by aggregation.

Ontario Hydro is experimenting with an approach to end-use forecasting that relies on a series of regional models (4.4). Each one will be supplied with historical data, forecasts of socio-economic variables – population, income, households, etc. – and external data – levels of appliance ownership, electric energy consumption per appliance, etc. The regional models forecast energy demand by highly disaggregated end use.

The end-use forecasts can be aggregated as desired. Load factors can be applied to the energy forecasts to get forecasts of area peak demands. The load factors may be forecast, or it may be assumed that the historical load factors continue unchanged. Area peak demands can then be compared with the area forecasts produced by other means.

End-use forecasting is still under development. It was not used in the preparation of the 1979 load forecast.

Evaluation of the Load-Forecasting Procedure

The medium-range forecast is based on forecasts supplied by customers and on the results of an econometric model. The long-range forecast is obtained by applying the coefficients of an econometric model to a long-run economic forecast. To evaluate the load forecasting procedure it is necessary, therefore, to review the forecasts supplied by customers and the econometric model.

Customer Forecasts

Ontario Hydro asks its municipal and direct industrial customers to prepare forecasts. The demands of retail customers are forecast by Hydro regional offices.

The municipalities normally have a public utility commission (PUC), or an equivalent body, which is responsible for purchasing electricity wholesale from Ontario Hydro and distributing it to the customers in the community. Hydro regional managers send a formal request to each PUC in their region about October of each year asking for its forecast. The PUC is asked to forecast its peak demand month by month for the coming two years and its December peak demand for the next four years after that. The request also asks for details of large changes in load that might be caused by residential, commercial, or industrial developments.

As may be imagined, there is considerable variation among municipalities in the care and skill that goes into their estimates. Testimony given to the RCEPP suggests that many customers simply use a ruler to project a plot of the historical peaks. Some make the projection on a linear scale so that a

declining growth rate results. Others use semi-log paper and so forecast a constant annual growth rate.[5]

It was found that most PUCs spend about two days on this exercise. Although they take the estimates seriously, the exercise does not have high priority. The PUC forecasters indicated in testimony before the RCEPP that they do not have the training or the data they would need in order to produce technically advanced forecasts.[6]

The first year of the forecast is normally used by the municipality for its own financial planning. This provides a quality control incentive. Ontario Hydro also monitors how well the municipalities have forecast in the past. The track record is one of the factors used in disaggregating the unallocated load to municipalities. Those that traditionally overestimate have their estimates reduced and underestimators have theirs boosted, other factors being equal.

In spite of the many limitations, Ontario Hydro receives a lot of detail about local conditions through this process.

A request is also sent to approximately 80 direct industrial customers. It asks for their expected peak demand month by month for the next two years and for December peaks over the next four years after that. The forecast is usually prepared by the utilities manager or plant manager. The most common approach for the industrial customers is to base their estimates on the facilities they expect to have and the level at which they expect to operate them.

Historical loads are used as a starting point. These are related to the plant capacity and production levels, to arrive at historical peaks per unit of plant throughput. The historical loads are adjusted to reflect anticipated production levels, changes in facility efficiency, the effects of energy conservation, and installed capacity. The result of these adjustments is the load forecast.

Most industries make an estimate of their production levels for a few years ahead. Such an estimate is most reliable for the year immediately ahead. Estimates for two or more years ahead are usually based on sales forecasts. These are not a reliable basis for long-term forecasts. Many industries do not have sales forecasts for six years into the future (five years is normally the maximum). Significant changes to production facilities are usually known only one to three years ahead.

As far as conservation is concerned, most industries have programmes but they are usually directed towards fossil fuels. Electric energy is, for most industries, a small part of the total energy bill, so conservation efforts directed towards saving electricity tend to be quite limited. Anticipated results of conservation have been included in recent forecasts. Many industrial customers, like the PUCs, use the forecast in budget preparation.

Ontario Hydro reviews the forecasts of some firms. The frequency of such reviews is approximately related to the historical difference between forecast and actual demand. This suggests that a reasonable quality control procedure is being followed by Hydro.

There is no commitment by the PUCs or direct industrial customers to consume or purchase any amount overestimated. On this basis, one would expect them to forecast on the high side to ensure supply. Individuals involved in the preparation of forecasts for the PUCs and direct industrial customers stated to the Commission that they attempt to make their forecasts as accurate as possible.

The Econometric Model

The technical details of the econometric model are given in Appendix A. The econometric model is formulated so that the variables are multiplicative. To estimate such a model it is necessary to take logarithms of the variables. The estimated coefficients of such a model are what economists call elasticities. An elasticity of −0.45 for the demand price of electricity means that a 1 per cent increase in the demand price of electricity would reduce the peak demand for electricity by 0.45 per cent.

The econometric model for the East System December peak was estimated using data for the period 1957-78. Both the short- and long-run elasticities were estimated. The short-run elasticity gives the effect during the first year. The long-run elasticity gives the eventual total effect of a 1 per cent change in the specified variable.

The econometric model for the East System December peak is given below.

Variable logarithm of constant (−10.41)	Elasticity – short-run	Elasticity – long-run
Real output/employee	1.12	1.34
Employment	1.45	1.26
Demand price (peak charge)	−0.412	−0.465
Energy price (energy wholesale rate)	−0.127	−0.167
Oil price	−0.129	−0.10
Gas price	−0.043	−0.041
Temperature[a]	−0.00013	N.A.

Note a) Degrees Fahrenheit at 5 p.m. (not logarithm). Electricity and gas prices lagged one year.

The statistical properties of the model are quite good. The conventional statistical tests indicate that the model as a whole and the individual variables are significant. This means that we can be confident – we can never be absolutely positive – that the model accurately describes the changes that occurred.

Two aspects of the model are disturbing. They are the lack of "dummy variables" for the post-1973 period; and the signs of the elasticities for oil and gas prices.

Circumstances may change in such a way as to cause a significantly different response to one or more variables. This possibility can be tested statistically by the use of dummy variables. There is reason to believe that the dramatic rise in oil and gas prices late in 1973 may have changed the way people use energy and also the way they use electricity. This hypothesis could be tested by means of a dummy variable. The dummy variable would have the value zero for each year through 1973 and the value one for each year thereafter. Depending on the formulation, the dummy variable could be used to test whether one or more of the coefficients is significantly different after 1973. There is not yet enough data to test whether all of the coefficients are significantly different after 1973.

The possibility that some of the coefficients might be different during the post-1973 period was not tested. Such tests are not difficult to make. Their absence was particularly surprising in the light of the signs of the elasticities for oil and gas prices.

The estimated elasticities of oil and gas prices received the following comment by Ontario Hydro:[7]

> It is perhaps significant that the estimated long term elasticities in the model for oil and gas are lower than the short run estimates. It is also worthy of note that the signs for these fuels are negative, suggesting that they complement electricity in the short run rather than act as substitutes. In the short run, they may very well complement one another.
>
> Oil heated houses tend to heat water electrically and gas heated houses generally have electric circulating fans or pumps. In another sense, falling prices for oil and gas may have stimulated the Ontario economy, with subsequent price increases serving to retard it, with the demand for electricity moving in sympathy.
>
> In the long run, however, one would expect to see substitution, especially if the price of oil and gas moves upward while the price of electricity is declining. The model cannot capture this effect, but it suggests it, insofar as the long-run estimates of elasticity are closer to zero than the short-run estimates. It therefore suggests that the impact of another oil supply crisis might be initial depression and subsequent expansion in the demand for electricity. It also suggests that orderly price increases in oil and gas may stimulate the demand for electricity in the long run. But it is not possible to provide a quantitative estimate.

The model, in short, implies that an increase in the price of oil or gas will reduce the demand for electricity both in the short run and in the long run. As the Ontario Hydro comment indicates, this is logically very difficult to accept, particularly in the long run.

The explanation offered in the 1979 load forecast is unacceptable, as it stands. Simply put, this explanation is that oil prices affect the province's economic growth which in turn affects the peak demand for electricity. This explanation could also be tested statistically. It requires that a second equation be added to the model. This second equation would relate the rate of economic growth to oil and gas prices and other relevant variables. The estimated coefficients of the December peak demand equation would then be free of such interactive effects. The explanation was not tested in this way. The fixed relationship between the prices of oil and natural gas in recent years may also have contributed to the problems with these variables.

The econometric model, in summary, has excellent statistical properties. But it also has some disturbing aspects that have not been resolved. Techniques that might have resolved these problems were not used.

The model deals only with the December peak. Historically, the annual peak always occurred in December. In recent years this has changed. Reduced Christmas lighting, among other things, has changed the circumstances to such an extent that the annual peak often occurs in January. A model to forecast the annual peak, regardless of when it occurs, is more appropriate for the load-forecasting process than a model of the December peak.

The econometric model is used to prepare a medium-range – to 1985 – forecast of the December peak. This is a simple process. Values of the independent variables are forecast for each of the six years. These are then multiplied by the corresponding short-run elasticities to get the forecast December peak for each year.

There is no fixed procedure in Ontario Hydro for making a long-term forecast. Each year a procedure is evolved that attempts to use historical knowledge and to incorporate any new events or developments that might affect the long-term demand. The procedure described here is the one that was used for the 1979 load forecast.

The long-term growth in primary peak demand is estimated as an annual rate of growth by adding a contribution from the following factors: economic growth, the price of electricity, the price and supply of oil, and substitution (primarily solar).

The long-run economic growth is forecast from the anticipated growth of employment and productivity. The average economic growth rate for each five-year period is multiplied by 1.3, the long-run elasticity for economic growth, to get the growth in primary peak demand. The price effect is obtained by multiplying the estimated price increase by the long-run price elasticity.

The effects of oil price, oil supply, and substitution are estimated by judgement. Each of these factors adds to (or subtracts from) the annual growth rate of primary peak demand, producing a net annual growth rate. Growth rates are calculated for four periods: 1980-85, 1985-90, 1990-95, and 1995-2000. During each period the growth rates are taken to be constant.

The individual factors and their net effect on primary peak as estimated by Ontario Hydro are given in Table 3.1. It is clear from the table that the long-range forecast is essentially based on the forecast of real economic growth. All of the other adjustments tend to offset each other. The net impact of these adjustments on the forecast rate of growth of primary peak demand is small.

Table 3.1 Long-Range Growth of Primary Peak Demand (average annual rate of growth)

Factor	1980-85 (%/year)	1985-90 (%/year)	1990-95 (%/year)	1995-2000 (%/year)
Real economic growth	4.25	3.7	3.3	3.1
Change in the real price of electricity	2.40	−1.07	−0.65	0.51
Components of the rate of growth of primary peak demand				
Economy output[a]	5.52	4.80	4.29	4.03
Electricity price[b]	−1.49	0.68	0.41	0.32
Cyclical recovery of economy output	1.00			
Oil price escalation and shortage		−0.60		
Substitution and solar energy competition			−0.20	−0.30
Load management				
Net primary peak demand growth rate	5.03	4.88	4.0	4.05

Notes:

a) Obtained by multiplying the rate of real economic growth by 1.3 the long-run elasticity.

b) Obtained by multiplying the change in the real price of electricity by [(−0.465) + (−0.167)] = −0.632 the long-run price elasticity.

Source: Ontario Hydro "Requirements for Additional Bulk Power Facilities in Southwestern Ontario: Information Relating to the 1979 Load Forecast." Toronto: Ontario Hydro, 1979.

Historical Load Growth and Forecasting Performance

The rate of growth of demand for electricity in Ontario has been impressive. Over the 40 years from 1937 to 1977 the December primary peak has grown from 1,068.0 to 15,676.7 MW. This is an average annual growth rate of 6.95 per cent. Over the same period the demand for electrical energy has grown at a rate of 7.18 per cent per year. The difference is accounted for by an increase in the load factor.

Statistical models of the demand for electricity have been estimated from the historical data. Regardless of the period selected, the results are much the same. The estimated model has good statistical properties. And the average annual rate of growth of demand for electricity is close to 7 per cent.

Models based on historical data against time alone do not give information about what might happen in the future to change the historical pattern. The dramatic increases in oil prices of 1973-4, for example, have caused a dramatic change in the energy situation. This has created an environment in which forecasting solely on the basis of historical performance is no longer adequate.

Until the early 1970s, Ontario Hydro's forecasting performance was outstanding by any measure. Table 3.2 compares the actual East System and West System peaks with the forecasts made five to 10 years earlier. The growing length of the forecast period reflects the increasing lead times needed for planning.

The forecasts for the years through 1973 consistently underestimated the East System December primary peak by five to 10 per cent. Since 1974, the forecasts have overestimated the actual by increasing amounts. The West System is much smaller and hence more difficult to forecast.

Prior to 1973 the West System forecast exceeded the actual December primary peak by less than 10 per cent. Since then, the extent of the overestimation has increased markedly.

The excellent performance of Ontario Hydro's past forecasts is often cited as support for its current forecasts. The performance of the forecasts for the post-1973 period is much poorer than those of the preceding period. This suggests that the traditional forecasting methods are no longer completely satisfactory. Hydro has been working to improve its forecasting methods. Our review of these methods indicates that there is scope for further improvement.

Table 3.2 Ontario Hydro Forecasting Performance (December primary peak)

	East System				West System			
Year of actual	Year of forecast	Forecast (GW)	Actual (GW)	Error (%)	Year of forecast	Forecast (GW)	Actual (GW)	Error (%)
1967	1958	8.12	8.40	3.3	1962	0.61	0.56	–8.9
1968	1959	8.69	9.39	7.5	1963	0.62	0.61	–1.6
1969	1960	9.30	9.92	6.2	1964	0.65	0.63	–3.2
1970	1961	9.73	10.64	8.6	1965	0.69	0.68	–1.5
1971	1962	10.10	10.87	7.1	1965	0.74	0.69	–7.2
1972	1963	10.72	12.00	10.7	1965	0.79	0.75	–5.3
1973	1964	12.20	12.86	5.1	1966	0.86	0.75	–14.7
1974	1965	12.90	12.90	0.0	1967	0.95	0.72	–31.9
1975	1966	13.99	13.97	–0.1	1968	0.92	0.56	–64.3
1976	1967	15.57	15.08	–3.2	1969	0.98	0.86	–14.0
1977	1968	17.31	14.85	–16.6	1969	1.05	0.85	–23.5
1978	1969	19.04	15.52	–22.7	1969	1.12	0.85	–31.8
1979	1970	20.28			1970	1.16		

Percentage of Error = (actual – forecast)/actual × 100

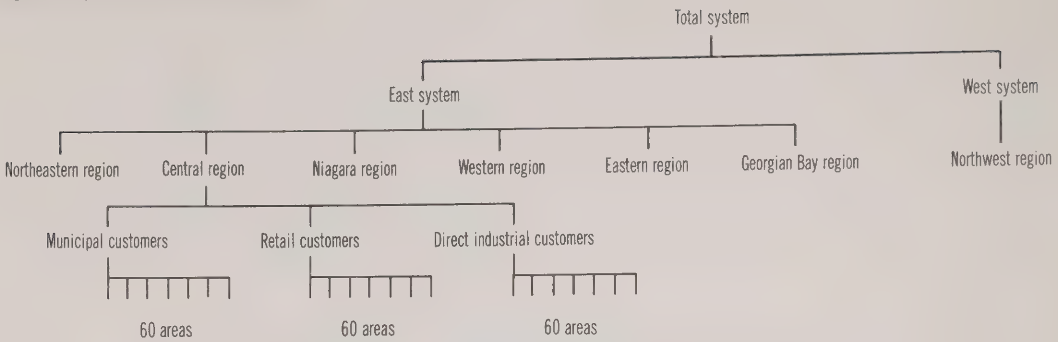
Source: Ontario Hydro Load Forecast 1979, Regions and Marketing Branch, Report No. 780213.

Summary

Ontario Hydro requires an elaborate set of forecasts of demand for electricity. The forecasts must cover both the peak and energy demands. They must extend far enough into the future to cover the planning and construction of new generating facilities. And they must be subdivided into relatively small geographical areas. Until the early 1970s, Ontario Hydro's forecasting performance was outstanding by any measure. More recent forecasts are much poorer, suggesting that the traditional methods are no longer completely satisfactory.

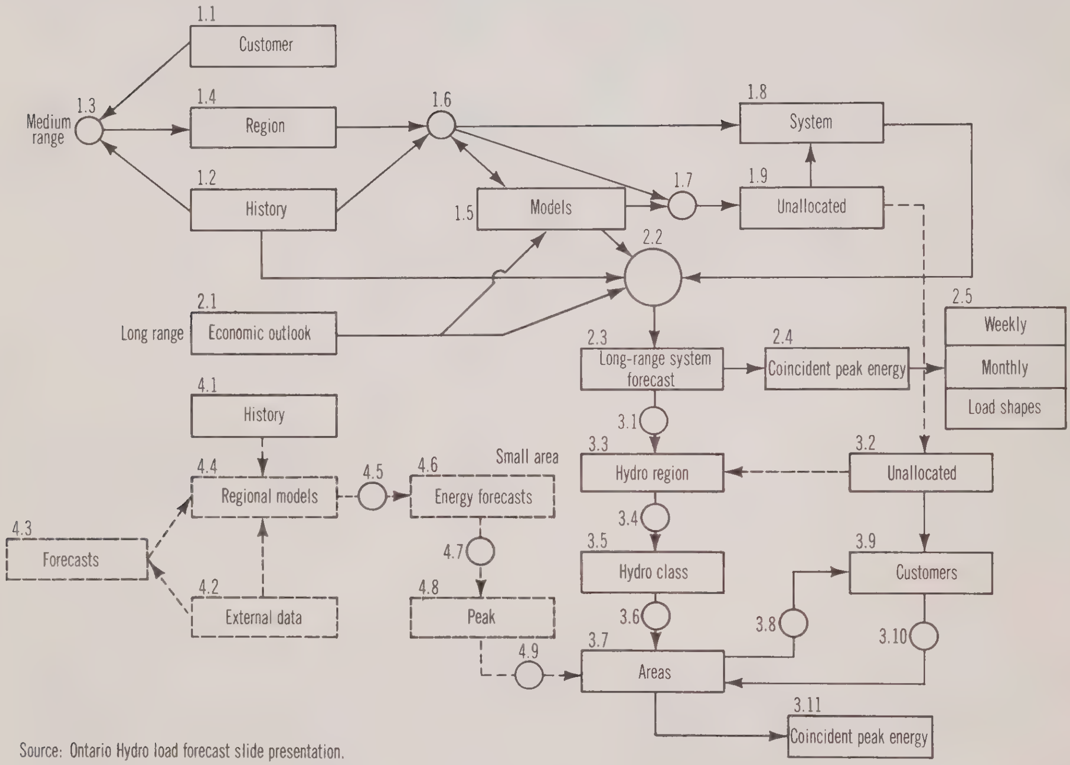
The medium-term forecast is based on forecasts supplied by PUCs and direct industrial customers and on a forecast prepared by means of an econometric model. The overall quality of the forecasts supplied by the PUCs and direct industrial customers is lower than is desirable. There is no practical alternative source of geographically disaggregated forecasts. The econometric model has excellent statistical properties, but it also has some disturbing aspects that have not been resolved. Techniques that might have resolved these problems were not tested.

Figure 3.1 System Structure and Customer Hierarchy



Source: RCEPP.

Figure 3.2 Long-range Forecasting Process



Source: Ontario Hydro load forecast slide presentation.

CHAPTER FOUR

Comprehensive Energy Demand Projections

Over the last few years a number of comprehensive energy demand projections have been produced by a variety of public and private agencies in Canada and abroad. The studies were conducted under widely differing time and budget constraints. They focused on different aspects of the future supply of and demand for energy. The result is a rich and diverse collection of projection techniques.

This chapter compares a number of the recent comprehensive energy demand projections for Canada and Ontario. The comparison focuses on the projection methods used, the assumptions made, and the energy projections derived. In many cases, the principal concern was a particular form of energy, usually nuclear-generated electricity or petroleum. Yet in all cases the total demand for energy was projected. The total demand was then used as the basis for projecting the demand for each individual energy form. Generally, forecasting the demand for total energy is likely to produce more reasonable results than those resulting from forecasting the demand for each energy form separately. These advantages have led to greater use of comprehensive or total energy demand projections.

Projection Methods

Energy demand projections generally cover a relatively long period, typically 10-50 years. This relatively long projection horizon is necessary because of the long lead times required to plan and construct energy supply and distribution facilities, and because of the long lead times required to convert energy-using facilities.

A long-term energy projection consists of three elements: a demographic projection, an economic projection, and an energy demand projection. There are, of course, variations in the approach used for each of these elements and in the relative importance attributed to each by various studies.

Generally, the demographic projection is made by the component method. This technique forecasts births, deaths, and net migration during a specified period (one or five years). These components are used to adjust the population at the start of the period and so yield the population at the end of the period.

Long-run economic growth is traditionally forecast by projecting the increase in employment and increases in productivity. The growth in employment is calculated from the projected working-age population, using forecast participation rates and unemployment rates. Increases in productivity are forecast on the basis of past experience.

Some studies use econometric models to make the economic projections. In the past such models were not considered reliable for long-term forecasting. Recent improvements in model-building techniques have allowed the development of econometric models that are judged to be reliable for forecasting up to 10 or 15 years ahead.

The energy demand projections relate energy demand in various end-use sectors to the projected demographic and economic variables. The major differences between models arise from the number of sectors and the types of relationships used. Most models use at least four sectors – residential, commercial, industrial, and transportation. Some models employ a much greater disaggregation, with as many as 100 or more sectors.

Energy demand models use two types of relationships – econometric and technical. Econometric relationships specify behavioural patterns derived from the statistical analysis of historical data. The statistical analysis is able to estimate the effects of changes in energy prices and incomes on energy demand. Conservation regulations, past or future, are not measured and hence cannot be included in the estimated relationships. Thus, the econometric relationships have the advantage of incorporating the effects of anticipated changes in incomes and energy prices, and the disadvantage of not incorporating the effects of proposed conservation regulations on the demand for energy.

Technical relationships specify the technical characteristics of alternative processes. Thus, the energy required for residential space heating may be related to factors such as type of unit (single-detached or apartment), insulation standards, and weather conditions. Technical relationships do not take into account the effects of changes in energy prices. But they are capable of assessing the impact of proposed

conservation measures or technological changes. The advantages and disadvantages of the technical model, then, are exactly the opposite of those of the econometric model.

Virtually all of the energy demand models proceed sequentially. They forecast population, then economic growth, then energy demand. It is widely recognized in these studies that feedback mechanisms exist at numerous stages in this sequence. For example, economic conditions are known to affect fertility rates and net migration and hence population. The energy situation can likewise affect economic growth. These feedback effects are, with the exception of a few U.S. models, usually not included in the models. To include them would greatly increase the complexity of the models. The magnitude of the feedback effects is judged to be relatively small – not sufficient to justify the additional effort.

Canadian Energy Demand Projections

Workshop on Alternative Energy Strategies (WAES), 1976[1]

WAES undertook an assessment of energy demand and supply for non-communist countries. Demand projections were made separately for each of the developed countries included in the study. An aggregate projection was prepared for the less developed countries.

Projections are made for each of several scenarios. Two periods – 1977-85 and 1985-2000 – are studied. During the first period, the scenarios are defined in terms of the world rate of economic growth (3.5 or 6.0 per cent annual growth of GNP), the world price of oil (constant, rising by 50 per cent, or falling by one-third), and national government policy (restrained or vigorous efforts to introduce conservation measures and increase supplies). The world conditions are assumed to apply in each country.

Energy use is divided into seven subsectors: transportation, primary industries, construction, commercial, public, industrial, and residential. Each subsector has a simple technical relationship to project energy demand. The energy demand for the subsector (e.g., urban auto) is projected as the product of an economic activity level (e.g., kilometres travelled) and an energy-use efficiency (e.g., kilometres per litre). The energy-use efficiency coefficient incorporates the effects of the various conservation measures expected to be implemented.

It is interesting to note that WAES used energy prices to define the scenarios. Yet the energy demand methodology developed uses technical relationships, which do not explicitly provide for the effects of price changes. The effects of price changes on energy demands must be incorporated into the calculations by adjusting the economic activity levels and/or energy-use efficiency coefficient.

The method used to project the economic activity levels for the subsectors was not specified by WAES. Obviously, relatively complex demographic and economic models are required to ensure that the economic activity levels of all of the subsectors are mutually consistent and that they are consistent with the specified growth rates and oil prices.

The basic tool used to prepare the Canadian projection was the energy demand forecasting model of the Department of Energy, Mines and Resources.

Department of Energy, Mines and Resources (EMR), 1977[2]

The EMR energy demand model was developed to assist in the development of Canadian energy policy. The model projects the total energy demanded by each of seven end-use sectors: residential, commercial, industrial, road transport, air transport, marine transport, and rail transport.

The total energy demanded by each of these sectors is projected for each of the following regions: Atlantic; Quebec; Ontario; Prairies; and British Columbia, the Yukon, and the Northwest Territories. For each sector in each region, the total demand is subdivided into demands for 12 specific fuels. The specific fuel demands are summed and converted to their primary forms.

A flow chart of the model structure is given in Figure 4.1. The total energy demand by sector and by region is projected by means of statistically estimated equations. Typically, the demand for energy is a function of independent variables relating to level of activity (e.g., number of households, real retail trade), income (e.g., real personal disposable income per household), and energy prices (e.g., real industrial energy price index). Fig. 4.1: p. 39

Use of the EMR model to project energy demand requires two types of inputs: price assumptions and regional economic projections. Price assumptions are required over the projection period for the residential, commercial, industrial, and road transport sectors. The prices are projected by a separate price

projection programme. The regional economic projections are derived from simulations of the so-called CANDIDE econometric model. This model produces both demographic and economic projections. CANDIDE is a national model, so the national economic variables have to be disaggregated to the regional level, using fairly arbitrary assumptions.

The model structure does not provide for non-price conservation measures, such as automobile mileage standards and building codes.

National Energy Board (NEB), 1978[3]

The NEB uses its long-term energy demand forecasting model to assist in its regulatory activities, particularly with respect to petroleum and natural gas.

The general structure of the model is similar to the EMR model. As with the EMR model, two types of input are required for the energy demand projections: regional economic projections, and price projections.

The CANDIDE model is used to forecast economic and demographic variables at the national level. Regional values of these variables are judgementally forecast.

The price projections are derived from a separate energy price programme. This programme takes assumptions such as the price of international crude oil landed at Montreal and Vancouver, the price of domestic crude relative to international crude, and the price of domestic natural gas relative to domestic crude oil. It also applies the relevant transportation, refining, and distribution margins. The result is a set of "burner tip" prices by region, sector, and major energy type.

Total energy demand is projected for each of seven end-use sectors. Energy demand projections for rail, air, and marine transport are made on a national basis. Energy demands in the road transport, residential, commercial, and industrial sectors are projected separately for each of five regions: Atlantic; Quebec; Ontario; the Prairies; and British Columbia, the Yukon, and the Northwest Territories.

Typically, the demand for energy is a function of independent variables relating to level of activity, incomes, and energy prices.

Market shares for the various fuel types are projected for each end-use sector and region. These projections are developed separately, on the basis of an analysis of historical trends, projected relative energy prices, and miscellaneous market intelligence. The market shares are applied to the corresponding projections of total energy demand to give the projected demand for each fuel type by end-use sector and by region.

The NEB model, as with the EMR model, relies primarily on econometric relationships to project energy demand. These relationships do not incorporate specific conservation measures. The impact of conservation measures must be estimated separately. The demand projections produced by the model must then be adjusted to reflect the estimated impact of the proposed conservation measures.

Institute for Research on Public Policy (IRPP), 1978[4]

This study makes a relatively simple projection of the Canadian demand for energy without wholesale changes in our way of life. The bulk of the work concentrates on seeking sources of energy to satisfy these projected demands. The demographic and economic models used are not explicitly described. It can be inferred from the text that the component method was used for the demographic projection. Similarly it can be inferred from the text that the economic projections were made by means of the classic long-run economic forecasting model. The labour force growth is estimated from the demographic projection. The increase in productivity is projected on the basis of historic experience.

Secondary energy demand is projected by using the following technical relationship.

Growth rate of secondary energy demand$_t$ *equals* growth rate of real GNP$_t$ *multiplied by* 1.0 *minus* aggregate conservation effect$_t$.

The conservation measures likely to be implemented over the next 22 years are considered for each of five end-use sectors. The estimated reduction in energy consumption below current levels, by the year 2000, is as shown:

Residential and farm – 35%
Commercial – 30%
Industrial – 25%
Automobile – 40%

Bus, truck, rail, air, and marine – 20%
Total – 30%

These estimates imply that the aggregate conservation effect for the year 2000 has a value of 0.3. Thus, values of the "aggregate conservation effect", increasing from zero up to 0.3 are substituted into the technical relationship for each year from 1979 through 2000.

Two reduced demand scenarios are considered possible. The "superconservation" scenario features the same rate of economic growth as the base scenario, but the conservation effort is estimated to produce a 42 per cent saving, thus reducing the energy growth rate to 1.22 per cent per year. The "low-growth" scenario uses a 2 per cent annual rate of growth of GNP. This slow growth reduces the opportunity for introducing conservation measures, but still reduces the energy growth rate to 0.85 per cent per year.

Long-Term Simulation Model (LTSM), 1977[5]

The LTSM is a strategic simulation model of the Canadian economy. It is intended to be a computational framework within which alternative scenarios or forecasts can be examined from the point of view of resource availability, technological feasibility, and internal consistency. The LTSM is not specifically an energy demand model. But it can be used to simulate energy demand under alternative scenarios.

The schematic structure of the LTSM is shown in Figure 4.2. The model consists of three major submodels – the demographic, final demand, and production sector models. The demographic model calculates population by means of the component method. The number of households is calculated by applying "headship" rates to various age-sex categories in the population. The labour force is estimated by applying projected participation rates to various subcategories in the working-age population. Fig. 4.2: p. 40

Final demand is separated into government and consumer demands and capital supplies. The model user specifies a relatively small number of aggregate demand variables in these categories. The model distributes those aggregates among 664 goods and services. The energy demands for residential private transportation and some commercial purposes are estimated from the final demands.

The production sector is an input-output model. It is assumed that the production technology for each of the 664 goods and services is fixed. These goods and services are produced by 210 industrial sectors. The output mix of each industrial sector is assumed to be fixed. The energy demands for industrial uses, public transportation, and some commercial purposes are estimated from the production sector.

The energy demand projections of the LTSM are derived from several hundred simple technical relationships. In each case the energy demand per unit of output or final demand is assumed to be constant initially.

Because of the structure of the model, some of the relationships have a much greater impact on the overall forecast than others. Residential energy demands are derived from a few relationships, while industrial energy demands are derived from over 100 different relationships. Efforts are under way to improve this situation. Specifically, a household energy demand model is being developed to improve the residential energy demand projections.

The LTSM model assumes that the technological structure of the economy and the level of energy conservation are fixed at their current levels. Both of these assumptions can be changed. Technological change is introduced by changing the input-output coefficients for existing industries or by adding new industries to the input-output model. Energy conservation is introduced by modifying the coefficients relating energy demand to output or final demand. Since there are several hundred of these coefficients, making these changes for each time period can become a tedious process.

Energy, Mines and Resources — Long-Term Energy Assessment Program (LEAP), 1978[6]

The report entitled *Energy Futures for Canadians* contains a projection of energy demand in Canada for the period 1975-2025. The specific approach used to develop the projections is not outlined. The notes to the report indicate that the demand projections are based primarily on the results of three special studies for the LEAP programme:

- D.B. Brooks, R. Erdmann, and G. Winstanley, "Some Scenarios of Energy Demand in Canada in the Year 2025". Ottawa: Report of the Demand and Conservation Task Force, 1977.
- J. Robinson et al., "Canadian Energy Futures". Toronto: York University, 1977.

- Delphic Consulting Ltd., "2025 Vision: Social and Economic Implications of Alternative Energy Futures: A Planner's View". Victoria: Delphic Consulting Ltd., 1977.

It appears that the demand projections reported constitute a consensus of the results of these studies.

D.B. Brooks, 1978[7]

The purpose of Brooks's work is to assess the economic implications of low energy growth for Canada. In the short term, 1975-90, the benefits and opportunity costs of specific conservation options are evaluated. For the long term, 1990-2025, the direct and indirect effects of overall low energy growth are evaluated.

The starting point for the long-term analysis is a low energy growth projection for Canada. The specific projection selected is the "low income/low industry" scenario from the Brooks, Erdmann, and Winstanley study. This scenario yields a reduction in secondary energy consumption of 0.2 per cent per year over the 50 years.

The LTSM model is then used to assess the economic impact of the low energy growth projection. The analysis concludes that the Canadian economy can accommodate the necessary shifts while maintaining reasonable growth in output, employment, and income and without demanding major life-style adjustments on the part of Canadian households.

Ontario Energy Demand Projections

Haites and Sullivan, 1978[8]

The Ontario Ministry of Energy commissioned the development of models of secondary energy demand in Ontario. Models were developed for the following sectors: transportation, industrial, and residential and commercial. The commercial energy demand model that was developed proved difficult to apply, given the data available. For this reason, the Ministry subsequently developed a model for the commercial sector internally.

The models project secondary energy demand. Where possible, the energy used to transport fuels and the energy consumed by energy-related industries is excluded. Self-generated electricity is explicitly included. The models relate secondary energy demand to a range of demographic and economic variables. Projecting these variables on a consistent basis requires the use of demographic and economic models. Those models are not, however, integrated with the energy models.

The four sectorial models were developed by four different groups. As a result of this and other factors, such as data availability, they have significantly different structures. All have a relatively large number of subsectors. They do not include any price variables. They consist strictly of technical relationships, some of which are statistically estimated.

The models calculate the demand by subsector for each fuel type. In some cases, such as small household appliances, there is very little scope for substitution among fuel types. The projection of demand by fuel type is simple in those cases. In most subsectors, however, some substitution among fuel types is possible. The market shares held by the various fuel types must be projected separately and put into the model for those subsectors. The projections of energy demand by fuel type generated by these models are, therefore, largely a reflection of these externally generated market share assumptions.

Energy Probe, 1978-9[9]

This study established a target for energy consumption and then identified means of achieving the target. The target established a maximum end-use energy consumption of $2{,}650 \times 10^{15}$ J for Ontario in the year 2025. The interim target for the year 1993 is $2{,}371 \times 10^{15}$ J. The analytical process must be an iterative one, although only the final results are presented. Each iteration imposes additional conservation measures until the targets are realized.

The analysis employs technical relationships in the four major economic sectors – residential, commercial, industrial, and transportation.

The basic determinants of residential energy consumption are the number of households, the mix of dwelling types, the quality of thermal insulation in space-heating and water-heating applications, and

the ownership and intensity of use of appliances. The number of households is derived from a demographic projection. The housing stock is projected on the basis of replacement demand and the net increase required. The residential energy demand is then related to the projected housing stock.

The projected labour force is divided between commercial and other employment. Energy consumption in the commercial sector is directly related to the number of employees. Energy requirements per employee for space heating and other purposes are projected to decline.

Energy demand in the transportation sector is divided into 17 categories. The four principal categories are urban and non-urban freight transport and urban and non-urban passenger transport. Within each of these categories the relevant modes of transport are distinguished. The demands for passenger and freight transportation services are related to population and industrial production, respectively. The corresponding energy demands are adjusted to reflect projected efficiency improvements, modal shifts, and changes in load factors.

Industrial energy demand is related to projected industrial output. Industrial output is divided between energy-intensive – primary metals, chemicals and chemical products, paper and allied products, non-metallic mineral products, and food and beverages – and other industries. The energy-intensive industries are projected to grow more slowly and to achieve greater energy savings than the other industries.

The 1993 target is achieved by means of a decline in the transportation demand and a relatively large growth in industrial demand. The demand for electric energy is found to grow at 1.4 per cent annually to 1993, which is well above the total energy demand growth of 0.6 per cent.

Sierra Club of Ontario, 1978[10]

The Sierra Club of Ontario commissioned studies (by Fuss and Waverman and Canadian Resourcecon Ltd.) that project electric energy demand for Ontario.

Fuss and Waverman develop econometric models of the demand for energy in the industrial, commercial, and residential sectors. The industrial sector model is a cost-minimizing firm. The firm uses four aggregate inputs – energy, labour, capital, and materials – to produce its output. To satisfy its energy needs the firm chooses from among six energy types – electricity, natural gas, heavy fuel oil, gasoline, liquefied petroleum gas, and coal. Details of the statistical estimates are not presented. However, the principal factors influencing energy demand are the prices of the various fuels.

The commercial sector model uses two sets of equations. One set relates total energy consumption to real commercial output and the average real price of energy. The second set determines the share of each type of energy in the total energy demand. The share of each energy type is determined by the real commercial output, the price of the fuel relative to the average for other fuels, and the shift from single to multiple dwellings.

Residential energy demand is determined by household income, the prices of various fuels, the consumer price index, deviations from the average annual mean temperature, and the shift from single to multiple dwellings.

> The Sierra Club believes that price alone may not be sufficient to curb the growth of our electric system. Consequently, other measures . . . should be implemented to supplement those decreases in consumption which will result from higher prices.[11]

Canadian Resourcecon Ltd. projected the impact of specific conservation measures on the demand for electricity in the residential, commercial, and industrial sectors. Details of their approach were not provided. It is likely, given the conservation measures considered, that the model uses engineering relationships. The base forecast is substantially higher than that produced by Fuss and Waverman, particularly in the industrial sector.

Comparison of Projections

It should be apparent from the foregoing descriptions, despite their brevity, that the energy demand models differ markedly in the details of their calculations. Any comparison of assumptions and projections must therefore be based on the aggregate variables.

The variables chosen to reflect the assumptions are demographic (total population, number of households) or economic (labour force or employment, productivity improvement, real GDP). Since the models relate to different areas and cover different periods, the variables are expressed in terms of average

annual growth rates. The projections are likewise expressed as annual growth rates. When available, the projected total energy demand is given by end-use sector. The demand for electricity, in total and by end-use sector, is also given when available.

Table 4.1: p. 38

The assumptions and projections are compared in Table 4.1. Despite attempts to encompass a wide range of possible developments, the assumptions and projections are remarkably similar. The rate of population growth assumed for Canada ranges from 0.9 to 1.6 per cent per year. Growth in employment is assumed to be between 1.5 and 2.8 per cent annually. The rate of productivity increase forecast is generally between 1.5 and 2.5 per cent per year. The rate of growth of real GDP derived from these assumptions ranges from 3.2 to 5.3 per cent per year. The more recent projections tend to fall in the lower part of the range – 3.5 to 4.0 per cent annual growth of real GDP.

The projections of the rate of growth of demand for energy in Canada range from 2.0 to 4.2 per cent per year. The projections are consistent in showing the lowest rate of energy demand for energy in the residential sector. No consistent pattern emerges from the projections for the other sectors.

The projections of electric energy demand in Canada imply rates of growth ranging between 4.0 and 6.0 per cent annually.

The energy-intensity results for the LTSM projections are not representative. No conservation measures were projected. Nor were price increases projected. As a result, the projected conservation effect is approximately zero – the current energy consumption practices are assumed to continue unchanged. All of the other projections envisage conservation gains ranging between 0.5 and 2.5 per cent per year.

The projections of the rate of growth of demand for energy in Ontario generally range between 2.0 and 3.0 per cent per year. The principal exception is the Energy Probe study which sets a low energy growth target (about 1 per cent per year to 2000) and determines the measures necessary to achieve this.

The forecast rates of growth of demand for electricity, again with the exception of the Energy Probe study, are between 2.0 and 5.5 per cent per year. The forecasts for Ontario are lower than the corresponding figures for the whole of Canada.

Summary

A number of comprehensive energy demand models for Canada and Ontario were reviewed. It was found that a long-term energy projection consists of a demographic projection, an economic projection, and the energy demand projection. The models differ in the approaches they take towards each of these elements.

The energy demand projections relate energy demand in various end-use sectors to the projected economic and demographic variables. Two types of relationships are used – econometric and technical. Econometric relationships are derived from the statistical analysis of historical data and usually include variables such as incomes and energy prices. Technical relationships are based on the technical characteristics of the energy-using process. For example, the demand for gasoline is related to the number of miles driven and the average gasoline consumption per mile. Each type of relationship has advantages and disadvantages.

Despite the diversity of the models, the projections are remarkably similar. The rate of growth of demand for energy in Ontario is generally projected to range between 2.0 and 3.0 per cent per year. The forecast rates of growth of demand for electricity lie between 2.0 and 5.5 per cent per year.

Table 4.1 Comparison of Assumptions and Projections of Selected Energy Demand Forecasting Models
(All figures are percentage annual growth rates)

	Demographic assumps		Economic assumptions				Energy demand projections					Electricity demand projections					Energy intensity
	Population	Households	Labour force	Employment	Productivity	Real GNP	Residential	Commercial	Industrial	Transportation	Total	Residential	Commercial	Industrial	Transportation	Total	
Projections relating to Canada																	
WAES projections, 1976-85[a]																	
Scenario A	1.55	2.80	–	2.80	2.50	5.3	1.1	3.8	2.3	3.0	3.0	5.2	6.3	3.5	–	4.8	2.3
Scenario B	1.25	2.40	–	2.25	2.25	4.5	0.8	3.2	2.3	2.7	2.7	5.0	5.7	3.5	–	4.5	1.8
Scenario C	1.55	2.80	–	2.80	2.50	5.3	1.2	3.8	2.8	3.2	3.2	5.4	6.3	4.0	–	5.0	2.1
Scenario D	1.25	2.40	–	2.25	2.25	4.5	1.3	3.2	3.2	3.9	3.5	5.5	5.7	4.5	–	5.1	1.0
Scenario E	1.55	2.80	–	2.80	2.50	5.3	2.0	4.4	4.0	4.6	4.2	6.2	6.8	5.4	–	6.0	1.1
LTSM projections, 1975-2000[b]																	
Case A	0.94	1.86	1.52	–	0.7	2.25	–	–	–	–	2.7	–	–	–	–	–	–0.4
Case B	0.94	1.86	1.52	–	1.8	3.25	–	–	–	–	3.4	–	–	–	–	–	–0.2
Case C	0.94	1.86	1.52	–	2.0	3.5	–	–	–	–	4.0	–	–	–	–	–	–0.5
LEAP Programme, 1975-2000	1.1	–	–	1.4	2.0	3.4	1.0	2.3	2.9	2.7	2.4	–	–	–	–	4.0	1.0
Brooks ECC, 1975-2025	0.7	0.6	0.85	–	0.85	1.7	–0.9	–1.0	+0.3	0.0	–0.2	–	–	–	–	–	1.9
IRPP, 1975-2000	1.1	–	–	1.5–2.0	1.5–2.0	3.5	1.7	2.0	2.3	1.9	2.0	–	–	–	–	4.05	1.5
EMR, 1975-90																	
High price, high growth	1.6	2.8	–	2.8	2.5	5.3	1.1	4.4	3.3	4.5	3.5	–	–	–	–	5.5	1.8
High price, low growth	1.3	2.4	–	2.1	1.9	4.0	0.6	3.2	3.0	3.6	2.7	–	–	–	–	4.8	1.3
Low price, high growth	1.6	2.8	–	2.8	2.5	5.3	1.7	4.8	4.1	4.8	3.9	–	–	–	–	6.0	1.4
Low price, low growth	1.3	2.4	–	2.1	1.9	4.0	1.1	3.6	3.8	3.9	3.2	–	–	–	–	5.4	0.8
NEB, 1975-95	1.1	2.1	–	1.8	2.2	4.0	1.6	3.7	2.8	1.5	2.3	3.9	5.5	3.4	–	4.2	1.7
Projections relating to Ontario																	
NEB, 1975-95	–	–	–	–	–	–	1.8	4.1	2.6	0.9	2.3	4.1	5.3	3.7	–	4.4	–
Haites and Sullivan, 1975-2000																	
Minimum intervention	0.8	–	–	2.3	2.2	4.5	1.5	2.7	3.7	3.5	3.1	–	–	–	–	–	1.4
Conservation incentives	0.8	–	–	2.3	2.2	4.5	+0.2	2.4	3.4	2.0	2.4	–	–	–	–	–	2.1
Maximum conservation	0.8	–	–	2.3	2.2	4.5	–0.3	1.6	3.3	1.6	2.1	–	–	–	–	–	2.4
High electricity	0.8	–	–	2.3	2.2	4.5	–0.6	1.6	3.3	1.4	2.0	2.7	5.3	3.4	8.7	4.4	2.5
Ministry of Energy, 1975-2000[c]																	
Current trend case	1.2	2.0	–	–	–	4.3	0.7	1.4	2.8[f]	2.3	2.1	–	–	–	–	2.8	2.2
Uncertain oil and gas case	1.2	2.0	–	–	–	4.3	0.1	0.3	2.5[f]	1.1	1.4	–	–	–	–	2.8	2.9
Sierra Club of Ontario																	
Fuss and Waverman, 1976-85																	
Standard forecast	–	–	–	–	–	–	–	–	–	–	–	5.0	4.3	0.1	–	2.8	–
High electricity prices[d]	–	–	–	–	–	–	–	–	–	–	–	4.2	3.7	0.1	–	2.1	–
Constant electricity prices[e]	–	–	–	–	–	–	–	–	–	–	–	4.9	4.7	4.9	–	4.9	–
Cdn Resourcecon Ltd, 1974-93																	
Base case	–	–	–	–	–	–	–	–	–	–	–	4.9	6.5	4.9	–	5.4	–
Conservation case	–	–	–	–	–	–	–	–	–	–	–	3.6	4.8	2.9	–	3.7	–

Notes to Table 4.1

a) Factors that influence future economy, 1976-85

World economic growth rate: high (6%) or low (3.5%)

A, high; B, low; C, high; D, low; E, high

Oil price: rising ($17.25), constant ($11.50) or falling ($7.66)

A, 17.25; B, 17.25; C, 11.50; D, 11.50; E, 7.66

National policy response: vigorous or restrained

A, vigorous; B, vigorous; C, vigorous; D, restrained; E, restrained

b) The cases are distinguished only by the differences in the assumed rate of growth of productivity.

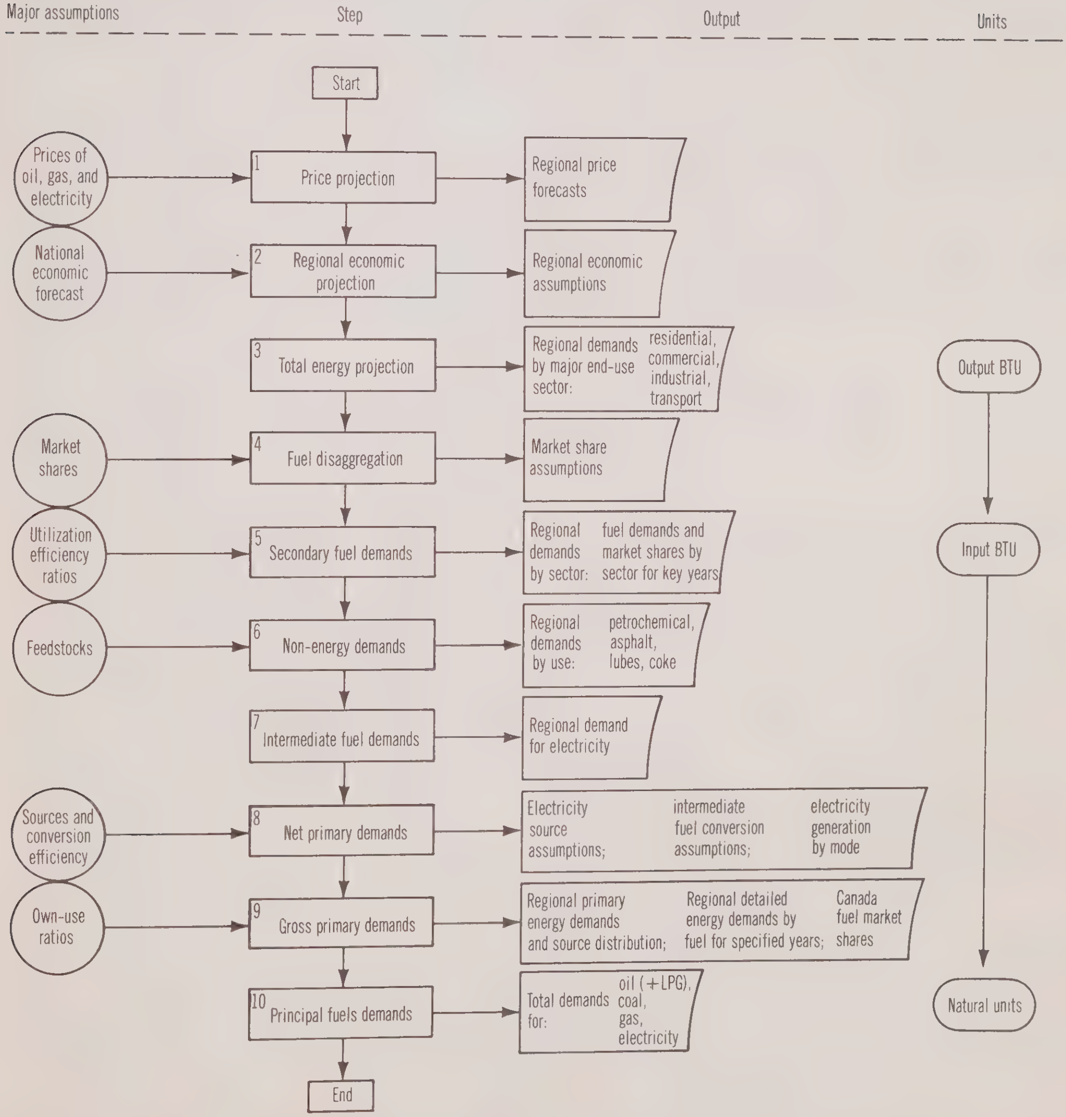
c) Ministry of Energy presentation to the Select Committee on Ontario Hydro.

d) Large price increases in electricity in commercial and residential sectors.

e) Electricity price growth equal to rate of inflation (approximately).

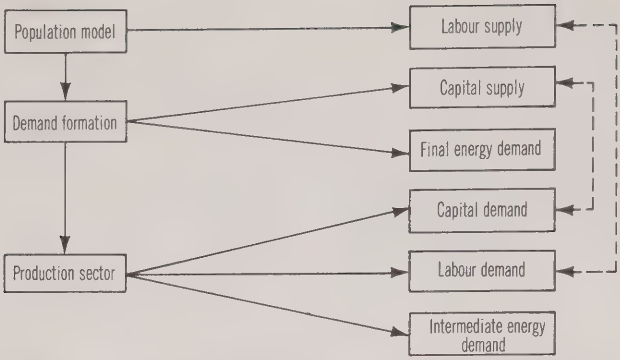
f) Excludes petrochemical use of fuels (unlike the Haites and Sullivan projects).

Figure 4.1 Flow Chart of EMR Energy Demand Model Structure



Source: "Energy Demand Projections—a Total Energy Approach". Ottawa: Energy, Mines and Resources, June 1977.

Figure 4.2 Long-term Simulation Model



Source: "Users' Guide to the Statistics Canada Long-term Simulation Model" by R.B. Hoffman and "Energy Futures: Scenarios and Postulations" by S.F. Gribble and K.E. Hamilton. Ottawa: Statistics Canada, 1977.

CHAPTER FIVE

Ontario Projections

The principal factors that affect the demand for energy in the long run were discussed in Chapter 2. The projection methods used in various studies to relate these factors to energy demand were reviewed in Chapter 4. This chapter develops a model to relate the demand for electricity to the demand for energy. This model classifies some demands – such as feedstocks and lighting – as "captive" to a particular fuel. The remaining demands define the range of substitution that is possible. Hence, it is possible to calculate the range of possible demand for electricity.

The demand for energy is projected by means of the major demographic and economic variables. The model is then applied to this energy demand projection to produce a projection of the demand for electricity in Ontario to 2000.

It must be stressed that the results are projections, not forecasts. A forecast attempts to predict what will happen. A projection indicates what would happen if certain assumed conditions were satisfied. Ontario's energy policies could have a significant impact on the demand for energy in the province. We cannot predict what these policies will be. Hence, we must regard our results as projections.

The purpose of the model will be to describe the relationship between the demand for electricity and the demand for energy. The relationship between the demand for energy and the demand for a given fuel is difficult to model. The available energy demand models incorporate two effects: differences in the rate of growth of the various economic sectors, and changes in the relative prices of the different fuels.

There are major differences in the mix of fuels used by each economic sector. The transportation sector, for example, uses petroleum products almost exclusively, while the industrial sector derives less than one-quarter of its energy needs from petroleum products. If the transportation sector is projected to grow more rapidly than other sectors, it will raise the rate of growth of demand for petroleum relative to that for other fuels.

The models that use econometric relationships generally have the ability to estimate the effects of changes in the relative prices of fuels on the demands for those fuels. These effects are calculated from the price elasticities. The econometric relationships that include price elasticities are usually highly aggregated. The relatively large amount of historical data required for the statistical estimation makes this necessary.

The models that use technical relationships use a specified fuel or mix of fuels for each process or end use. These are assumed to remain constant or to change in some specified manner. In either case there is at least an implicit assumption about the changes in relative prices and the effects of these changes.

These existing models are not completely satisfactory for our purposes. The principal difficulty with the models that use econometric relationships is that price elasticities cannot be considered constant over wide ranges. Hence, if the forecast conditions differ significantly from historical conditions the models may not be valid. To illustrate, consider a model that uses a price elasticity of demand for electricity in the industrial sector. Electricity is used for several purposes – lighting, motor drive, electrolytic processes, etc. – in the industrial sector. A small increase in the price of electricity would, if the price elasticity has the expected sign, lead to a specified reduction in demand for electricity. A large price increase, say 10 times the small increase, is not likely to achieve 10 times the reduction of the small increase, because it becomes progressively more difficult to reduce the demand for electricity in various applications. A minimum amount of lighting is required, and once this is reached load reductions must come from other applications. Despite these realities, an econometric relationship would predict that the large price increase leads to 10 times the reduction in demand of the small price increase.

The principal reason why the models with technical relationships are limited is that they do not provide a consistent basis for determining the fuels likely to be used for various purposes. For example, if supplies of oil are forecast to be limited, the users of home heating oil, motor gasoline, and heavy fuel oil, among others, will be affected. But will the supplies of these products all be reduced by the same percentage? In a model with technical relationships the answer to this question depends solely on the judgement of the user.

The model developed below considers the uses to which energy is put. Some of these uses – such as feedstocks and lighting – are classified as "captive" to a specific fuel. Together these account for

roughly one-half of the total energy demand. The remaining uses are those that allow considerable scope for substitution among fuels. The various combinations of fuels that can be used to satisfy these demands can then be examined.

Development of the Model

The development of the model proceeds in three steps, as follows:

- Calculate the relationships among growth rates for fuels. Given a forecast rate of growth of secondary energy demand and a forecast of renewables penetration, it is possible to calculate the feasible combinations of growth rates for individual fuels.
- Determine the range of feasible substitutions among fuels. The secondary energy uses must be classified as being either substitutable or captive to a specific fuel. Once the relative growth or decline of each use is forecast it is possible to determine the range of feasible growth rates for each fuel. The minimum growth rate is that required to satisfy only the demands captive to the fuel. The maximum growth rate is that required to satisfy the captive demands as well as all of the substitutable uses.
- Allocate the fuels among the substitutable uses. Rarely would it be the case that one fuel would satisfy all of the substitutable uses. Generally, several substitutable uses must be satisfied by several different fuels. Hence, procedures are needed to determine which fuels are used for each application and in what proportions.

The explanation in the following sections follows that outline.

Calculation of Relationships among Growth Rates for Fuels

No Renewables Penetration

Given a forecast rate of growth of secondary energy demand and a forecast of renewables penetration, it is possible to calculate the feasible combinations of growth rates for the individual fuels. This is strictly an arithmetic exercise. It requires no assumptions or theory.

This can be illustrated as follows. In 1975, the secondary demand for energy in Ontario was 2,009 $\times 10^{15}$ J of which 290 $\times 10^{15}$ J was for electricity and 190 $\times 10^{15}$ J was for coal.

The current target of Ontario's energy conservation programme is to reduce the rate of growth of demand for energy in the province to 2 per cent per year by 1985. For the purposes of the illustration, assume that the forecast rate of growth of secondary energy demand is 2.0 per cent per annum to 2000 and that the renewables penetration is zero. Then the total secondary energy demand in 2000 will be 3,296 $\times 10^{15}$ J.

Assume that the growth rate over this period for all fuels except electricity is zero so that the demand for those fuels is (2,009 – 290 =) 1,719 $\times 10^{15}$ J in 2000, as it was in 1975. Then electricity demand will grow from 290 to (3,296 – 1,719 =) 1,577 $\times 10^{15}$ J. This is an average annual rate of growth of demand for electricity of 7.0 per cent. Assume now that all fuels except coal have a zero growth rate, so that the demand for those fuels is (2,009 – 190 =) 1,819 $\times 10^{15}$ J in 2000, as it was in 1975. Then the demand for coal will grow from 190 to (3,296 – 1,819 =) 1,477 $\times 10^{15}$ J or at an annual rate of 8.5 per cent.

There are an infinite number of feasible combinations that can be calculated in this manner. All of them correspond to an average annual growth of secondary energy demand of 2 per cent to 2000 and no renewables penetration.

With Renewables Penetration

Consider now how the anticipated use of renewable energy sources affects these calculations. Currently, less than 1 per cent of Ontario's energy is derived from wastes or renewable sources (other than hydroelectricity). We anticipate a greater reliance on such sources in the future. The government of Ontario has set an overall target of supplying an additional 2 per cent of the province's energy needs from renewable sources in 2000. We will use the 2 per cent figure in our calculations.

It is important to note that the analysis is in terms of secondary energy. The assumption on renewables penetration, therefore, covers only the renewable energy, such as solar space heating and water heating, used to satisfy energy demands directly. The use of renewables to produce conventional energy forms – wind-, solar-, and biomass-generated electricity, for example – is not included in the assumption on renewables penetration. The model would treat the energy demands as being met by electricity.

The use of renewables alters slightly the calculation of the feasible combinations of growth rates. Assume again that total secondary energy demand grows at 2 per cent per year to $3{,}296 \times 10^{15}$ J in 2000. Two per cent of this, 66×10^{15} J, will be satisfied directly by renewables. The remaining $3{,}230 \times 10^{15}$ J must be supplied by conventional fuels. Assume that the growth rate for all fuels except electricity is zero, so that the demand for those fuels is $(2{,}009 - 290 =)\ 1{,}719 \times 10^{15}$ J in 2000, as it was in 1975. Then electricity demand will grow from 290 to $(3{,}230 - 1{,}719 =)\ 1{,}511 \times 10^{15}$ J, an average annual growth rate of 6.8 per cent.

There are an infinite number of feasible combinations of growth rates that can be calculated in this manner. All of them correspond to an average annual growth of secondary energy demand of 2.0 per cent to 2000 and renewables penetration of 2.0 per cent in 2000.

Fig. 5.1: p. 54 The feasible combinations of growth rates can be displayed graphically, as in Figure 5.1. Point A corresponds to zero growth for all fuels except electricity, which has a growth rate of 6.8 per cent. Similarly, point B corresponds to zero growth for all fuels except coal, which has a growth rate of 8.4 per cent.

To display the results graphically it is necessary to work in terms of three fuels. This is achieved by working with electricity, coal, and oil and gas combined. Any two of these principal fuels could have been combined. We judged oil and gas to be the most logical ones to combine. They are the closest substitutes and they are the scarce energy sources. Showing coal and electricity separately highlights the requirements for these fuels, given the scarcity of oil and gas.

Determination of the Range of Feasible Substitutions among Fuels

Classification of Energy Uses

The most common classification of secondary energy uses is by economic sector – residential, commercial, industrial, and transportation. The availability of data is one of the principal reasons for classifying them in this way. Another system of classifying secondary energy use is by type of application – space heating, lighting, feedstocks, motor drive, process heat, etc. Systems of this type are not widely used because the data are incomplete.

To assess properly the possibilities of substitution among fuels, it is essential to have some knowledge of the applications. Electricity cannot replace petroleum in its role as a feedstock. Conversely, petroleum is unlikely to displace electricity in lighting applications. Petroleum and electricity are, however, substitutes in space-heating and water-heating applications.

The Ontario Ministry of Energy models embody a substantial amount of information for the applications to which various fuels are put. The following classification of energy applications was developed using those models.

Residential
- space heating and water heating
- other applications

Commercial
- space heating and water heating
- other applications

Transportation
- all modes

Industrial
- petrochemical feedstocks
- metallurgical coal
- electrical processes
- steam generation
- process heat
- other applications

The applications in the residential, commercial, and transportation sectors are clearly distinguished in the models. The subdivision of energy demands by type of application in the industrial sector is more difficult. The demand for petroleum and natural gas for use as feedstocks in the industrial chemicals

industry is clearly identified in the model. Similarly, the demand for metallurgical coal for use in the iron and steel and iron foundry industries is clearly identified.

The electrical processes were defined as including the abrasives industry, electrolytic refining processes, chlorine production, paint-drying in the automobile manufacturing industry, and refrigeration in the food and beverage industry.

Similarly, steam generation applications were defined as including the pulp and paper industry, the industrial chemicals industry excluding feedstocks and electricity for chlorine production, and the food and beverage industry excluding refrigeration applications.

Process heat applications include the cement, clay, glass, and lime industries, and the iron and steel and iron foundry industries excluding the demands for metallurgical coal. The mining, milling, and smelting industries, excluding the electrolytic refining processes, are also included in this group.

The remaining industries -- agriculture, automobile manufacturing other than paint-drying, and other manufacturing -- constitute the other applications.

It is evident that the classification of industrial applications is somewhat arbitrary. This is necessary given the limitations of the data. It should be noted also that, in practice, the applications are not completely separable. For example, many industrial applications required steam heat when coal was the energy source. When natural gas became available it became possible to use direct heat because gas is a much cleaner burning fuel than coal.

Table 5.1 shows the share of secondary energy demand accounted for by each of the above applications. The 1975 figures are estimates of the actual values. For 2000 a range of values is given. This range is calculated from the scenarios developed by Haites and Sullivan.[1]

Table 5.1 Shares of Final Energy Demand Attributable to Selected Applications, 1975 and 2000

Application	1975[a] (%)	2000[b] (%)
Residential		
– space and water heating	18.3	8.9–12.1
– other applications	2.2	1.7–1.7
Subtotal	20.5	10.6–13.8
Commercial		
– space and water heating	6.8	4.8–6.1
– other applications	6.5	5.9–7.0
Subtotal	13.3	10.7–13.1
Transportation		
– all modes	28.1	25.5–30.4
Industrial		
– petrochemical feedstocks	3.2	7.7–9.7
– metallurgical coal	8.8	8.7–11.0
– electrical processes	0.8	0.8–0.9
– steam generation	8.5	9.7–10.7
– process heat	8.8	7.7–8.8
– other applications	8.0	9.3–11.1
Subtotal	38.1	43.9–52.2
Total	100.0	100.0

Notes:

a) Estimated actual.

b) Calculated from the range of scenarios developed by Haites and Sullivan.

Source: "Projections of the Final Demand for Energy in Ontario to the year 2000" by E.F. Haites and J.L. Sullivan, RCEPP, 1978.

It is apparent from the table that future energy applications are likely to be quite different from today's. Residential space heating and water heating will probably account for a much smaller share of total energy demand. Petrochemical feedstocks are likely to account for a larger share of total energy demand.

The change in the share of secondary energy demand attributable to an application is the net result of two effects: the relative growth of the economic sectors where the application is found, and the relative impact of conservation measures on the application.

The growth in the share of secondary energy demand attributable to petrochemical feedstocks is

primarily due to the anticipated growth of the industrial chemicals industry in the province. The decline in the share of secondary energy demand attributable to residential space heating and water heating reflects both a slowing down of the rate of household formation and the anticipated savings due to conservation measures. Some of the applications are supplied almost exclusively by a single fuel. Generally, there are technical or economic reasons for this. These reasons are likely to remain valid for the next two decades. It is likely that these applications will continue to be met by the same fuels. They may be considered "captive" to the respective fuels. The remaining applications are those where substitution among fuels is most likely to occur. These are designated "substitutable" applications.

With one exception, the applications shown in Table 5.1 are regrouped to produce Table 5.2. The exception is "other industrial" demand for electricity. Ontario Hydro surveys indicate that about 75 per cent of all electricity used by industrial customers is used for lighting and motor drive.[2] These captive uses are not isolated in the industry descriptions of the Ministry of Energy industrial sector model. Hence, it has been assumed that 75 per cent of the total industrial electricity demand is captive. All other industrial electricity demand is assumed to be used for process heat.

Table 5.2 shows the various types of applications regrouped as "captive" or "substitutable". The table indicates that, in 1975, 49.0 per cent of secondary energy demand was captive to given fuels. This is projected to rise to about 55.9 per cent by 2000. The increase occurs primarily in petroleum, natural gas, and coal. The share of secondary energy demand captive to electricity rises from 8.8 to 9.4 per cent of total demand.

Table 5.2 Shares of Final Energy Demand for Selected Captive and Substitutable Applications, 1975 and 2000

Captive applications	1975 Estimated (%)	2000 Average (%)	Range (%)
Electricity			
Other residential	2.1		1.6–1.6
Other commercial	2.2		2.0–2.3
Electrical processes	0.8		0.8–0.9
Other industrial	3.7		4.2–5.4
Subtotal	8.8	9.4	8.6–10.2
Petroleum and natural gas			
Other residential	0.1		0.1–0.1
Transportation	28.1		30.4–25.5
Petrochemical feedstocks	3.2		7.7–9.7
Subtotal	31.4	36.6	38.2–35.2
Coal			
Other residential	–	–	–
Metallurgical coal	8.8		8.7–11.0
Subtotal	8.8	9.9	8.7–11.0
Substitutable applications			
Space and water heating			
Residential	18.3		12.1–8.9
Commercial	6.8		6.1– 4.8
Subtotal	25.1	16.0	18.2–13.7
Process heat and miscellaneous uses			
Other commercial (non-electric)	4.3		3.9–4.7
Other industrial (non-electric)	4.3		5.0–5.7
Process Heat	8.8		7.7–8.8
Subtotal	17.4	17.9	16.6–19.2
Steam generation			
Steam generation	8.5	10.2	9.7–10.7
Total	100.0	100.0	100.0

Source: "Projections of the Final Demand for Energy in Ontario to the year 2000" by E.F. Haites and J.L. Sullivan, RCEPP, 1978.

The share of total energy demand accounted for by substitutable uses declines from 51.0 to 44.1 per cent. The largest substitutable use is space heating and water heating. The relative size of this application is expected to fall sharply. The relative sizes of the other substitutable uses are expected to grow slightly.

Some variation in the distribution of secondary energy demand among applications is evident from the figures given in the table. This is to be expected since they are projections. The variations are quite

small, considering the approximate nature of the definitions and basic data. For this reason only the average values will be used in the model.

Note that transportation is considered a captive application of the petroleum sector. Some substitution is possible in this sector by 2000. Specifically, there may be some use of electricity for railways and/or automobiles by 2000. The effect of such changes is judged to be sufficiently small that it lies within the existing range of error. The "high electricity" scenario in the Haites study indicates that 10 per cent of the transportation energy demand could be supplied by electricity in 2000.[3] This is equivalent to 2.5 or 3.0 per cent of the total energy demand, and would not be a captive demand for electricity. It would reduce the captive demand for petroleum by 2.5 or 3.0 per cent, an amount that is within the margin of error of the projected captive demand for petroleum products.

Comparison with Other Classifications

The Institute for Research on Public Policy (IRPP) reports that "55 per cent of all secondary energy [in Canada] is used as heat, 30 per cent for transport, 12 per cent for strictly electrical applications, and 3 per cent for petrochemical feedstocks".[4] These figures are quite similar to those of Table 5.2. The major differences are that the IRPP does not mention metallurgical coal, and that the IRPP figure for electrical applications is higher than that of Table 5.2. It is possible that most of the difference between the figures for electrical applications can be explained. The IRPP report indicates that about 25 per cent of electricity demand is for space heating and water heating, which is not a captive use of electricity. If the 12 per cent figure given by IRPP is reduced by one-quarter to exclude electrical space heating and water heating, the result (9 per cent) is very close to the 8.8 per cent figure given in Table 5.2.

The Institute for Energy Analysis (IEA) has provided some data on energy applications in the U.S. Those figures are regrouped in Table 5.3 to correspond as closely as possible with Table 5.2. The figures for the year 2000 are averages for the high and low scenarios.

Table 5.3 Shares of U.S. Final Energy Demand for Selected Applications, 1975 and 2000

Application	1975 (%)	2000 (%)
Electricity		
Other residential	5.3	4.9
Electricity	10.1	15.7
Subtotal	15.5	20.6
Petroleum and natural gas		
Transportation	26.2	22.1
Feedstocks	6.6	8.0
Subtotal	32.8	30.1
Space and water heating		
Residential	16.9	13.6
Commercial	8.4	6.6
Subtotal	25.3	20.2
Process heat and steam generating		
Other commercial	4.6	4.9
Iron and steel	3.9	3.4
Aluminum	1.1	1.8
Other process heat	16.9	19.0
Subtotal	26.4	29.1
Total	100.0	100.0

Source: Institute for Energy Analysis, "U.S. Energy and Economic Growth, 1975–2010", Oak Ridge, Tennessee; Oak Ridge Associated Universities, 1976.

There is a great deal of similarity between the data in Tables 5.2 and 5.3. The major differences for 1975 are that Table 5.3 does not identify metallurgical coal and that the electricity figure is higher than in Table 5.2. The projected pattern of change is similar for both sources. The higher percentage for electricity is probably explained by the fact that the IEA calculations are in terms of primary energy demand. They convert electricity at 10,600,000 J/kW·h. The figures of Table 5.2 are in terms of secondary energy, and electricity is converted on the basis of 3,616,720 J/kW·h.

The IEA expects a decline in transportation demand, whereas it remains constant in Table 5.2. The expected decline in space-heating demand is smaller in the IEA figures. Finally, IEA expects an increase in the captive electricity demand, whereas Table 5.2 keeps it constant.

Feasible Substitutions

Now that the energy uses have been classified, it is possible to define the range of feasible substitutions. This will be illustrated by means of a sample calculation.

The calculation is outlined in Table 5.4. It assumes a 2 per cent annual growth in secondary energy demand to 2000. It also assumes that 2 per cent of the secondary energy demand in 2000 will be supplied by renewables. The secondary energy demand in 2000 is split among the captive and substitutable uses. The energy supplied by renewable sources is deducted from the energy demand for substitutable applications. The remainder is the energy demand for substitutable applications that must be supplied by conventional fuels.

Table 5.4 Calculation of Feasible Substitutions Among Fuels (based on 2 per cent annual growth in secondary energy demand to 2000 and renewables penetration of 2 per cent of secondary energy demand in 2000)

Minimum growth rates

	Total demand in 1975 (10^{15} J)	Demand in 2000 as a percentage of secondary energy (%)	Demand in 2000 (10^{15} J)	Minimum growth rate (%/year)
Captive uses				
electricity	290	9.4	310	0.3
coal	190	9.9	326	2.2
oil and gas	1,529	36.6	1,206	−1.0
Substitutable uses				
total		44.1	1,454	
renewables		2.0	66	
conventional		42.1	1,388	
Total	2,009	100.0	3,296	2.0

Maximum growth rates

	Total demand in 1975 (10^{15} J)	Captive demand in 2000 (10^{15} J)	Substitutable demand for conventional fuels in 2000 (10^{15} J)	Maximum demand in 2000 (10^{15} J)	Maximum growth rate (%/year)
Electricity	290	310	1,388	1,698	7.3
Coal	190	326	1,388	1,715	9.2
Oil and gas	1,529	1,206	1,388	2,594	2.1

Source: RCEPP.

The minimum growth rate for each fuel is calculated by comparing the *total* demand for the fuel in 1975 with the *captive* demand in 2000. The minimum growth rates are found to be +0.3 per cent per year for electricity, −1.0 for oil and gas, and +2.2 for coal.

The maximum growth rate for each fuel is calculated by adding the entire demand for conventional fuels in substitutable uses to the captive demand for the fuel. This total is then compared with the 1975 total demand for the fuel. The maximum growth rates are found to be +7.3 per year for electricity, +2.1 for oil and gas, and +9.2 for coal.

Fig. 5.2: p. 54
The feasible substitutions are shown in Figure 5.2. The maximum growth rate for each fuel occurs together with the minimum growth rates for all other fuels. The maximum growth rates for coal, oil and gas, and electricity are labelled C, D, and E, respectively. These points are the extremities of a region of feasible solutions. The boundaries of this region are shown in the figure. All of the combinations of growth rates that lie within this region are feasible. For example, point F (4.0 per cent electricity, 1.0 per cent oil and gas, and 3.9 per cent coal) is a feasible combination of growth rates.

Allocation of Fuels among Substitutable Uses

Assignment of Fuels to Substitutable Applications

The feasible region defines the combinations of growth rates for the different fuels that will satisfy the secondary energy demand, including the substitutable applications in total. The next step is to assign specific fuels to specific substitutable applications.

Our model considers three substitutable applications: space heating and water heating, process heat, and steam generation. It also considers four fuels: electricity, coal, oil and gas, and renewables. The

problem is to devise a procedure for assigning the fuels – in the quantities estimated to be available – to the specific applications. The procedure will be kept as simple as possible.

The fuels used for each of the substitutable applications in 1975 were as follows:

Space heating and water heating
 oil and gas 84.4 per cent
 electricity 15.6 per cent

Process heat
 oil and gas 79.3 per cent
 coal 10.6 per cent
 electricity 10.1 per cent

Steam generation
 oil and gas 95.8 per cent
 coal 4.2 per cent

Notice that no coal was used for space heating and water heating and no electricity was used for steam generation. Nor were renewable energy sources used for any of these applications in significant quantities.

The procedure for assigning fuels to specific substitutable applications is as follows:

- All renewable energy is assumed to be used for space heating and water heating.
- Coal and electricity are assumed to maintain their existing shares of the process-heat demand, unless the quantities available are inadequate.
- Electricity is substituted for oil and gas, first in space heating, then in process heat, and finally in steam generation.
- Coal is substituted for oil and gas, first in steam generation, then in process heat, and finally in space heating.

Relationship of the Substitutable Uses for a Fuel to Its Growth Rate

In Table 5.4 we calculated the minimum and maximum feasible growth rate for each fuel. The minimum growth rate assumes that the fuel satisfies only its captive uses. The maximum growth rate assumes that the fuel satisfies its captive uses and all substitutable applications supplied by conventional fuels. When a fuel supplies some, but not all, substitutable uses, its growth rate will lie between the minimum and maximum feasible rates.

The procedure specified above relates the growth rate for a fuel to the substitutable applications for which it is used. This relationship is calculated for coal in Table 5.5.

First, the amount of secondary energy from conventional fuels must be determined for each substitutable use. The percentage of total secondary energy demand attributable to each of the uses is taken from Table 5.2. The amount of secondary energy required by each of the uses is calculated and the renewable energy is deducted from the space-heating and water-heating demand, as specified above. The totals for secondary energy required for substitutable uses, renewable energy, and energy required from conventional fuels tally with the figures in Table 5.4.

Coal is currently used for some substitutable uses – 10.6 per cent of process heat and 4.2 per cent of steam heat. If coal retains its share of the process-heat application, 62.5×10^{15} J will be required for this purpose in 2000. When this is added to the coal required for captive uses, it is seen that a total of 388.5×10^{15} J will be required in 2000. This represents an average annual rate of growth of 2.9 per cent. The coal required to retain the current share (4.2 per cent) of the steam-heating uses will raise the growth in demand to an average rate of 3.0 per cent per year.

Wider use of coal comes, by the procedure specified, first by its replacing oil and gas and then by its replacing electricity. Oil and gas are displaced first in steam heating, then in process heating, and then in space heating and water heating. To capture 50 per cent of the steam-heating market requires that coal displace oil and gas equivalent to (50.0 – 4.2 =) 45.8 per cent of the steam-heating demand. This would require 153.9×10^{15} J and an average annual growth rate of 4.4 per cent.

Use of coal for more of the substitutable applications progressively raises the average rate of growth of demand for coal. If coal is used for all of the substitutable uses, as well as for its captive uses, the growth in demand will average 9.2 per cent per year. This corresponds to the maximum growth rate calculated in Table 5.4.

Table 5.5 Relationship of the Substitutable Uses for Coal to Its Growth Rate

Conventional fuels required, by substitutable uses

Use	Percentage of total secondary energy (%)	Energy required in 2000 (10^{15} J)	Renewable energy used in 2000 (10^{15} J)	Conventional fuels used in 2000 (10^{15} J)	Percentage of total energy supplied by conventional fuels (%)
Steam heat	10.2	336		336	100.0
Process heat	17.9	590		590	100.0
Space and water	16.0	528	66	462	87.5
Total	44.1	1,454	66	1,388	95.5

Relationship of substitutable uses for coal to its growth rate

	Uses of coal	Amount of additional energy required from coal (10^{15} J)	Total amount of energy required from coal (10^{15} J)	Coal growth rate (%/year)
Existing uses of coal	Captive uses	326	326	2.2
	10.6% process heat	62.5	388.5	2.9
	4.2% steam heat	14.1	402.6	3.0
Existing uses of oil and gas	50.0% steam heat	153.9	556.5	4.4
	100.0% steam heat	168.0	724.5	5.5
	50.0% process heat	232.5	957.0	6.7
	89.9% process heat	235.4	1,192.4	7.6
	50.0% space and water	264.0	1,456.4	8.5
	71.9% space and water	115.6	1,572.0	8.8
Existing uses of electricity	87.5% space and water	82.4	1,654.4	9.0
	100.0% process	59.6	1,714.0	9.2

Source: RCEPP.

Fig. 5.3: p. 55

Figure 5.3 shows the relationship of the substitutable uses for coal and electricity to their respective growth rates. The figure provides the same information as the table, but gives more detail. Two points should be noted in the figure:

- Conventional fuels can supply a maximum of 87.5 per cent of the space heating and water heating demand. Renewable energy sources are assumed to supply the remainder. Renewables penetration of 2 per cent of the total secondary energy demand in 2000 corresponds to 12.5 per cent of the space-heating and water-heating demand. This is shown in Table 5.5.
- The market share scale is not linear. To move from 20 to 30 per cent of the space-heating and water-heating demand requires the same absolute increase in secondary energy (i.e., the same number of joules) as to move from 70 to 80 per cent of this market. This fixed amount of additional energy has a different impact on the growth rate in each case. The average annual growth in demand for electricity is increased by 0.43 per cent by the move to 30 per cent of the space-heating and water-heating market and by 0.29 per cent by the move to 80 per cent of this market.

Fig. 5.4: p. 56

These same scales relating the substitutable end-use penetration to the rates of growth of demand for coal and electricity are shown in Figure 5.4. The scale for electricity is on the right-hand side of the figure and the scale for coal is along the top. The implications of any feasible combination of growth rates can be read directly from Figure 5.4. For example, the point G corresponds to growth rates of 2.5 per cent for electricity, 3.7 per cent for coal, and 1.5 per cent for oil and gas. The electrical growth rate implies that about 32.5 per cent of the space-heating and water-heating demand will be captured by this energy source. The coal growth rate implies that about 25 per cent of the steam-generation demand will be met by coal. Oil and gas will supply the remainder of the substitutable applications – (87.5 – 32.5 =) 55 per cent of space heating and water heating, and (100 – 10.1 – 10.6 =) 79.3 per cent of process heat, and (100 – 25 =) 75 per cent of steam generation.

It is possible to embody in the scales more complex allocation procedures. For example, it can be assumed that electricity would be substituted for oil and gas more or less simultaneously in space heating and water heating and in process heating. One such scale is shown at the extreme right in Figure 5.4. This scale assumes that market penetration of electricity in space heating and water heating will rise roughly twice as fast as in industrial process heating. Any scale of simultaneous substitution requires an assumption about the relative rates of penetration.

Supply and Other Restrictions

The range of probable substitutions can be refined by imposing supply or other constraints. Assume, for purposes of illustration, that supplies of oil and gas will grow at an annual rate of between zero and 1.5 per cent to 2000. Also, assume that, to keep the capital costs manageable, supplies of electricity are limited to a 5 per cent rate of growth. Finally, assume that the rate of growth of coal supplies is limited to 8 per cent for environmental or other reasons.

The foregoing supply restrictions are imposed on the range of probable substitutions in Figure 5.5. Fig. 5.5: p. 57 They have the effect of reducing the feasible region to the shaded area. The range of possible rates of growth of demand for electricity under these constraints is 0.3 to 5.0 per cent per year to 2000. With a 0.3 per cent per year growth in demand, electricity is confined strictly to captive uses. The annual rate of growth of demand for coal must be at least 5.3 per cent and may be as high as 8.0 per cent, depending on the rate of growth of oil and gas supplies.

With a 5.0 per cent per year growth in demand, electricity meets all of the space-heating and water-heating demand and about 36 per cent of the process-heat demand. The demand for coal is limited to 2.2 to 5.5 per cent per year. The lower end of the range restricts the use of coal to its captive uses. Given the 5.0 per cent per year growth in demand for electricity and no growth in the demand for oil and gas, the 5.5 per cent per year growth in demand for coal is sufficient to satisfy all remaining energy demands. Note, also, that a 5.0 per cent per year growth in demand for electricity is only possible if the rate of growth of oil and gas supplies averages less than 1.0 per cent per year.

Other types of restrictions are also possible. As an example, the use of fuels for specific applications may be restricted. The use of coal for residential space heating and water heating may be prohibited for environmental reasons. This might limit the growth rate for coal to 7.6 per cent annually.

Sensitivity Tests

In the course of developing the model several assumptions were made. In this section, we will review the sensitivity of electricity growth rates to each of the following assumptions: renewables penetration, growth of energy demand in various applications, and use of electricity in the transportation sector.

Renewables Penetration

The growth rate for captive electricity is the same for a given rate of growth of total secondary energy demand regardless of the renewables penetration. This is because renewables are assumed to be used only for substitutable applications. However, the assumption about renewables penetration does affect the amount of electricity that can be used for substitutable applications, and hence the maximum electricity growth rate. The maximum electricity growth rates corresponding to various levels of renewables penetration and a 2 per cent annual growth of secondary energy demand are shown in Table 5.6.

Table 5.6

Renewables penetration[a] (%)	Maximum electricity growth rate[b] (%)
0	7.5
2	7.3
4	7.2
5	7.1
10	6.6

Notes:
a) Percentage of total energy demand in 2000.
b) Percentage per year.

It is clear that the results are not very sensitive to the renewables penetration assumption. A renewables penetration of 2 per cent will be used.

Growth of Energy Demand in Various Applications

Table 5.2 gave the share of final energy demand for selected applications in 2000. A range of values is given for each application. These values change the relative amounts needed for the various captive and substitutable uses in 2000. If the estimated amount needed for the captive uses for electricity in 2000 is raised, the minimum rate of growth in the demand for electricity will be raised. But this will also reduce the amount needed for some other uses, restricting the rate of growth of total secondary energy demand to 2.0 per cent per year. If some of the reduction is in the substitutable uses, the impact is less on the maximum rate of growth of demand than on the minimum rate of growth.

Fig. 5.6: p. 58

Figure 5.6 shows the feasible area defined by means of the average values of Table 5.2. It is identical to the feasible area shown in the preceding figures. The feasible areas corresponding to the extreme values of the ranges given in Table 5.2 are also shown in Figure 5.6. They indicate the sensitivity of the model to the forecast pattern of future demand.

The impact is greatest on the necessary electricity growth rate. This rate ranges from −0.1 to +0.6 per cent per year. The maximum electricity growth rate changes very little – from 7.55 to 7.65 per cent per year.

Use of Electricity in the Transportation Sector

The use of electricity in the transportation sector – for motor vehicles and railways – has two effects. It leads to a small reduction in the energy demand for transportation and so in total secondary energy demand. Also, it changes some of the transportation demand from a captive oil and gas application to a substitutable application. In terms of the impact on electricity growth rates, these two effects work in opposite directions. The necessary electricity growth rate is not affected. The maximum electricity growth rate – with a 2 per cent annual growth in total energy demand and a 2 per cent renewables penetration in 2000 – goes from 7.3 per cent with transportation captive to oil and gas to 7.6 per cent with 10 per cent electric use in this sector.

It is clear that for any projection of the electricity growth rate using the model the margin of error will be less than 0.5 per cent per year.

Projections

Energy Policies

The future demand for energy depends to a very large extent on the energy policies of the Government of Ontario and of other jurisdictions. The policies with respect to conservation illustrate this. In Chapter 2 a number of measures were described which, together, yield a 1.5 per cent per year reduction in energy demand in Ontario. In broad terms, these measures include improved insulation standards for buildings, improved appliance efficiency, improved fuel efficiency of automobiles, greater use of public transportation, and increased energy efficiency of industrial processes.

Some of these measures, automobile fuel efficiency, for example, require federal policies. Others, such as building codes, involve both the federal and provincial governments. Those areas that are under provincial jurisdiction, such as public transit, are a relatively small part of the total.

Since Ontario imports about 80 per cent of its primary energy supplies, its dependence on the policies of other jurisdictions is great. The focus of Ontario's energy policy has been to ensure adequate supplies of energy while attempting to protect consumers from rapid price increases. Ontario has attempted to shape national policies for coal, oil, and natural gas along these lines, but its influence is limited. It has taken a more active role in areas where it has more control – electric energy generation and distribution, energy conservation, and research and development of renewable energy sources.

Fundamental to Ontario's current energy policy is the concept of market determination of the energy future. The market is already overlain with a strong element of government intervention. Nevertheless, the Ontario position is that the market should be allowed to perform those functions for which it is well suited. In keeping with this market philosophy, Ontario has taken the position that economic considerations should be central to decisions regarding conservation programmes, the development and introduction of alternative energy forms, and major energy projects anywhere in the country.

Current Ontario policy considers the development of economically feasible sources to be crucial to its long-term energy future. It has set an overall target of supplying an additional 2 per cent of the

province's energy requirements in the year 2000 from renewable sources other than hydraulic. To achieve this target, Ontario has initiated programmes focused on three main areas: solar space heating and water heating, biomass energy from waste, and remote power systems. These programmes cover the residential, commercial, industrial, and transportation sectors.

The Ontario government has made a firm commitment to increased energy conservation and efficiency. In many respects, it is a national leader in the introduction of innovative conservation programmes. The current target of Ontario's energy-conservation effort is a reduction in the provincial annual rate of growth of demand for energy to 2 per cent by 1985. To achieve this, the government has initiated, funded, and is co-ordinating a variety of programmes directed at all sectors and all energy forms. The basic approach is to encourage voluntary energy conservation efforts based on enlightened self-interest as opposed to government mandate. Related to this basic position is the policy that energy prices should not be artificially escalated in order to achieve conservation objectives.

Reference Projection

The provincial government targets of a 2 per cent per year energy growth and a 2 per cent renewables penetration in 2000 will be used as the basis for the reference projection.

The range of feasible substitutions corresponding to these assumptions is rather large. A rationale for reducing the range of feasible substitutions to a much smaller range of probable substitutions must be devised. The availability of oil and natural gas determines the range of probable substitutions. These fuels now satisfy most of the substitutable energy demands. Oil and natural gas will continue to satisfy the substitutable demands as long as adequate supplies are available and/or their prices do not rise dramatically relative to those for coal and electricity. Under these circumstances, neither coal nor electricity will be able to displace oil and natural gas in substitutable applications to a significant extent.

Most projections of the availability of oil and natural gas supplies for Ontario indicate that these will grow at an average annual rate of 1.0 to 1.5 per cent. We will use the low end of this range. If oil and gas are available in larger quantities, it will reduce the growth in demand for coal and/or electricity.

Further restriction on the range of probable substitutions will be on the basis of the applications for electricity and coal. Electricity will be restrained to its current penetration of the industrial process heat market (10.1 per cent) and restricted to the available space-heating and water-heating market. The current market share is 15.6 per cent of space heating and water heating. To attain the maximum 87.5 per cent share in 2000 would require the use of electricity for all space-heating and water-heating demands that are not satisfied by renewables. This would require the use of electricity for space heating and water heating for all new residential and commercial units, and substantial retrofit. Coal, exclusive of the coal used to generate electricity, will be restrained to a maximum of 35 per cent of the industrial process-heat demand and 100 per cent of the steam-generation demand.

These constraints are shown in Figure 5.7. It is evident from the figure that the average growth in demand for electricity ranges between 1.5 and 4.3 per cent per year. These figures should be treated as being accurate to ± 0.5 per cent per year. The rate of growth of demand for coal, for purposes other than generation of electricity, ranges between 2.9 and 6.2 per cent per annum. Fig. 5.7: p. 59

Preferred Projection

The projected rates of growth of population, real GDP, reduction in energy intensity, and final energy demand for Ontario to 2000 were discussed in Chapter 2. They may be summarized as follows (percentages per year):

Population 1.0
Employment 1.6
Productivity 1.7
Real GDP 3.3
Energy intensity −1.55
Secondary energy demand 1.75

These projections are similar to those of several of the other energy demand forecasting studies reviewed in Chapter 4.

The preferred projection is shown in Figure 5.8. Applying the constraints discussed above in connection with the reference projection, we find the projected rate of growth of demand for electric energy to Fig. 5.8: p. 60

be between 1.6 and 3.6 per cent per year. It is unlikely that electricity will be able to capture all of the available space-heating and water-heating demand by 2000. For this reason, and given the accuracy of the model, we project the demand for electricity in Ontario to grow at an average rate of 3.25 ± 0.5 per cent per year to 2000.

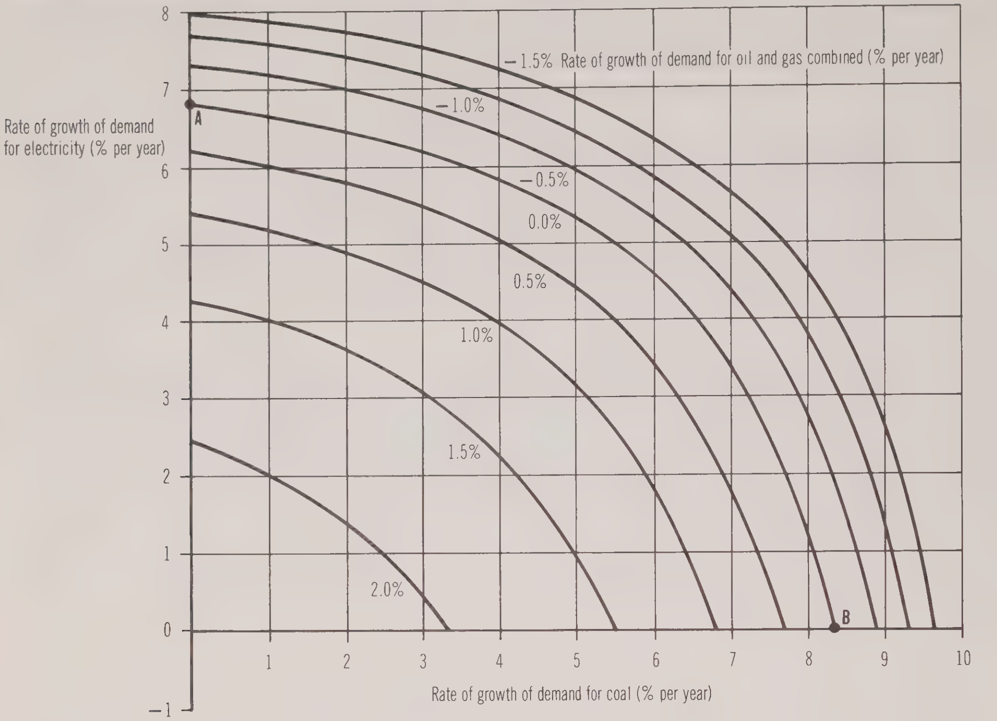
Summary

A model that relates the demand for electricity to the demand for energy in Ontario was developed. The demand for energy was estimated from the demographic, economic, and energy-intensity projections.

The model determines the feasible combinations of growth rates of demand for conventional fuels. It classifies the demands for energy as being captive to a specific form of energy or as substitutable among different forms of energy. Roughly half of the energy demand is captive to specific fuels. Finally, the model relates each rate of growth of demand for each form of energy to the market shares of the substitutable applications in the year 2000.

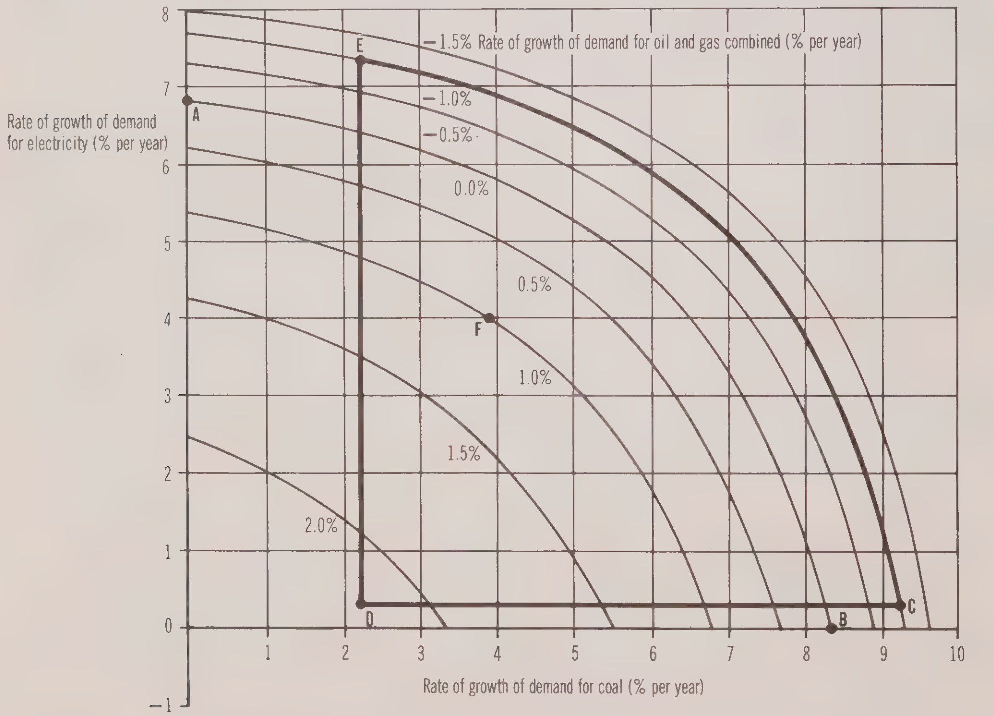
The preferred projection is based on a 1.75 per cent per year rate of growth of secondary energy demand in Ontario to 2000. It also anticipates that 2 per cent of the secondary energy demand in 2000 will be met by renewable energy sources. Constraints relating to the available supplies of oil and natural gas, and the possible applications for coal and electricity are applied. The resulting projection of the rate of growth of demand for electricity in Ontario to 2000 is 3.25 ± 0.5 per cent per year.

Figure 5.1 Feasible Combinations of Growth Rates for Conventional Fuels. Secondary Energy Growth 2% per Year to 2000 and 2% Renewables Penetration in 2000



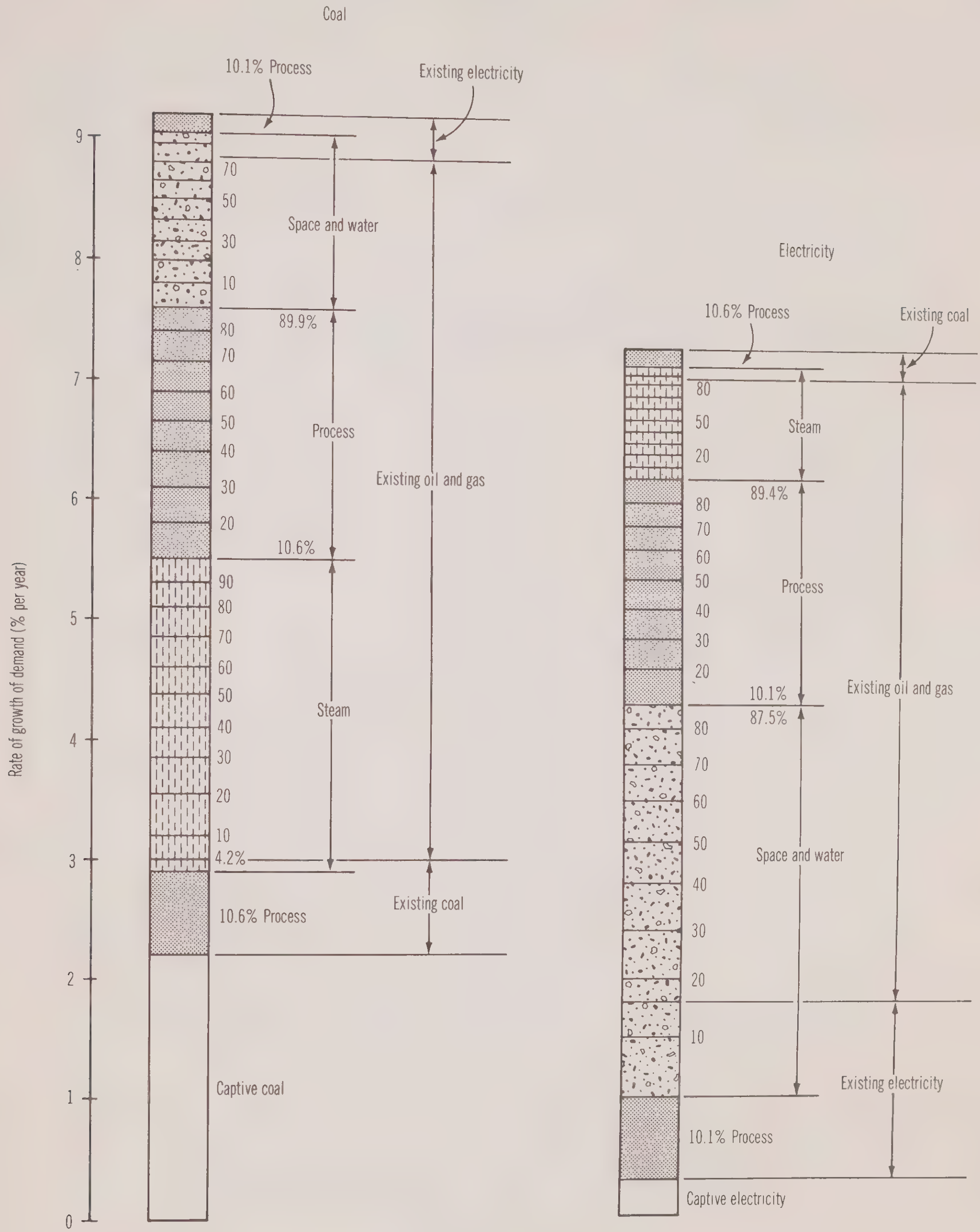
Source: RCEPP

Figure 5.2 Range of Feasible Substitutions among Conventional Fuels. Secondary Energy Growth 2% per Year to 2000 and 2% Renewables Penetration in 2000



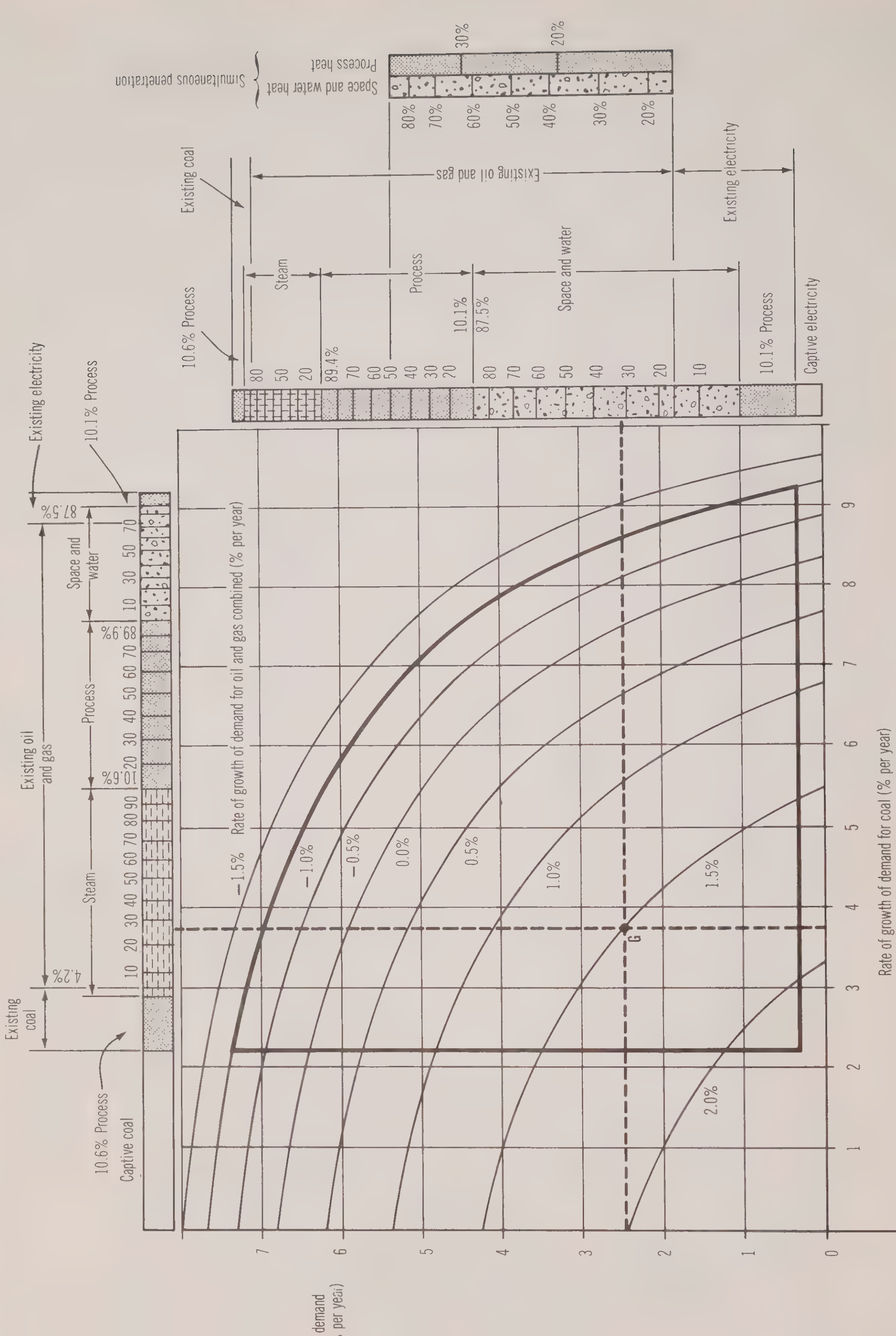
Source: RCEPP

Figure 5.3 Relationship of the Substitutable Uses for Coal and Electricity and Their Growth Rates



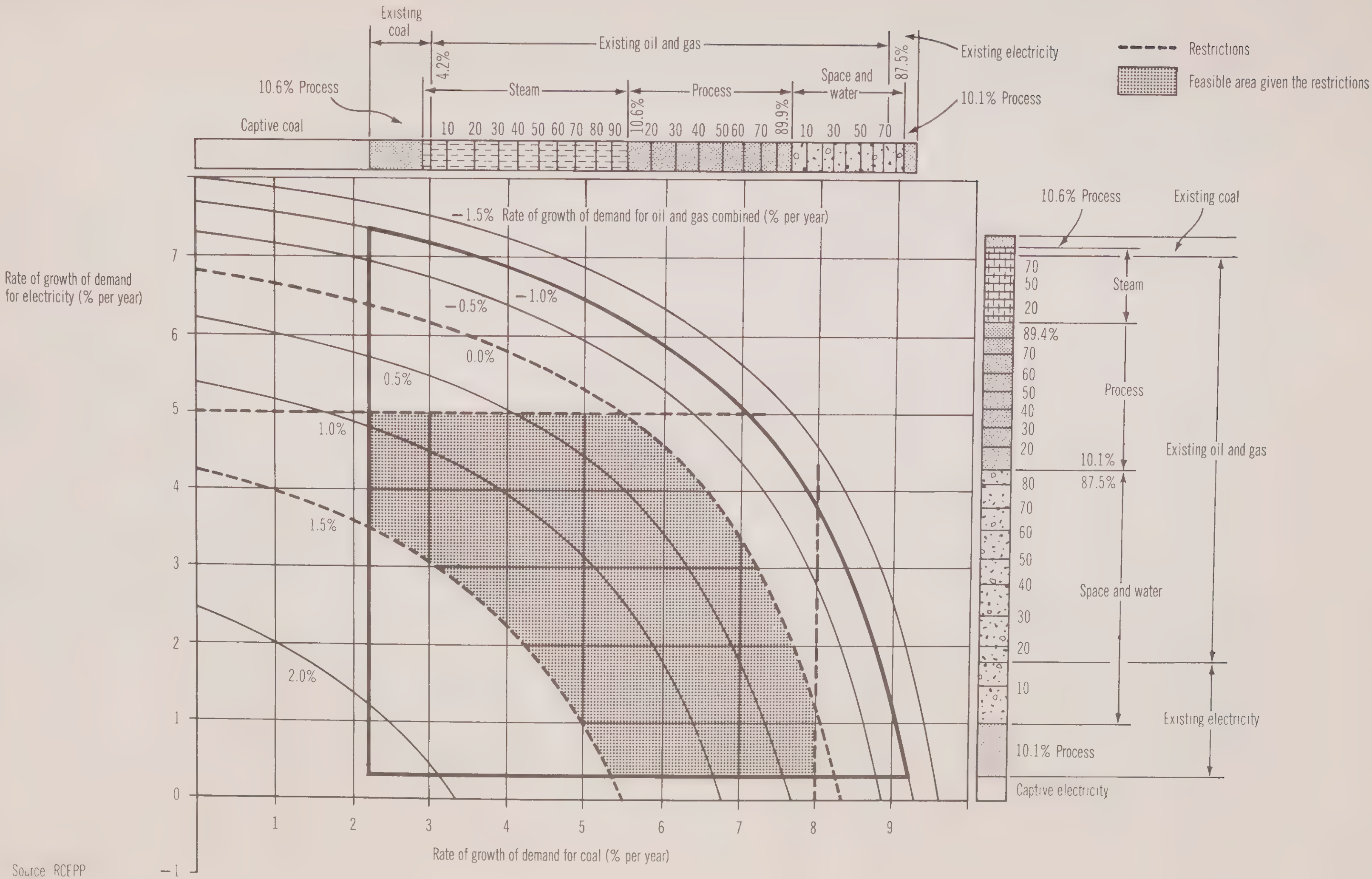
Source: RCEPP

Figure 5.4 Relationship of Market Shares in 2000 to Rates of Growth of Demand for Conventional Fuels. Secondary Energy Growth 2% per Year to 2000 and 2% Renewables Penetration in 2000



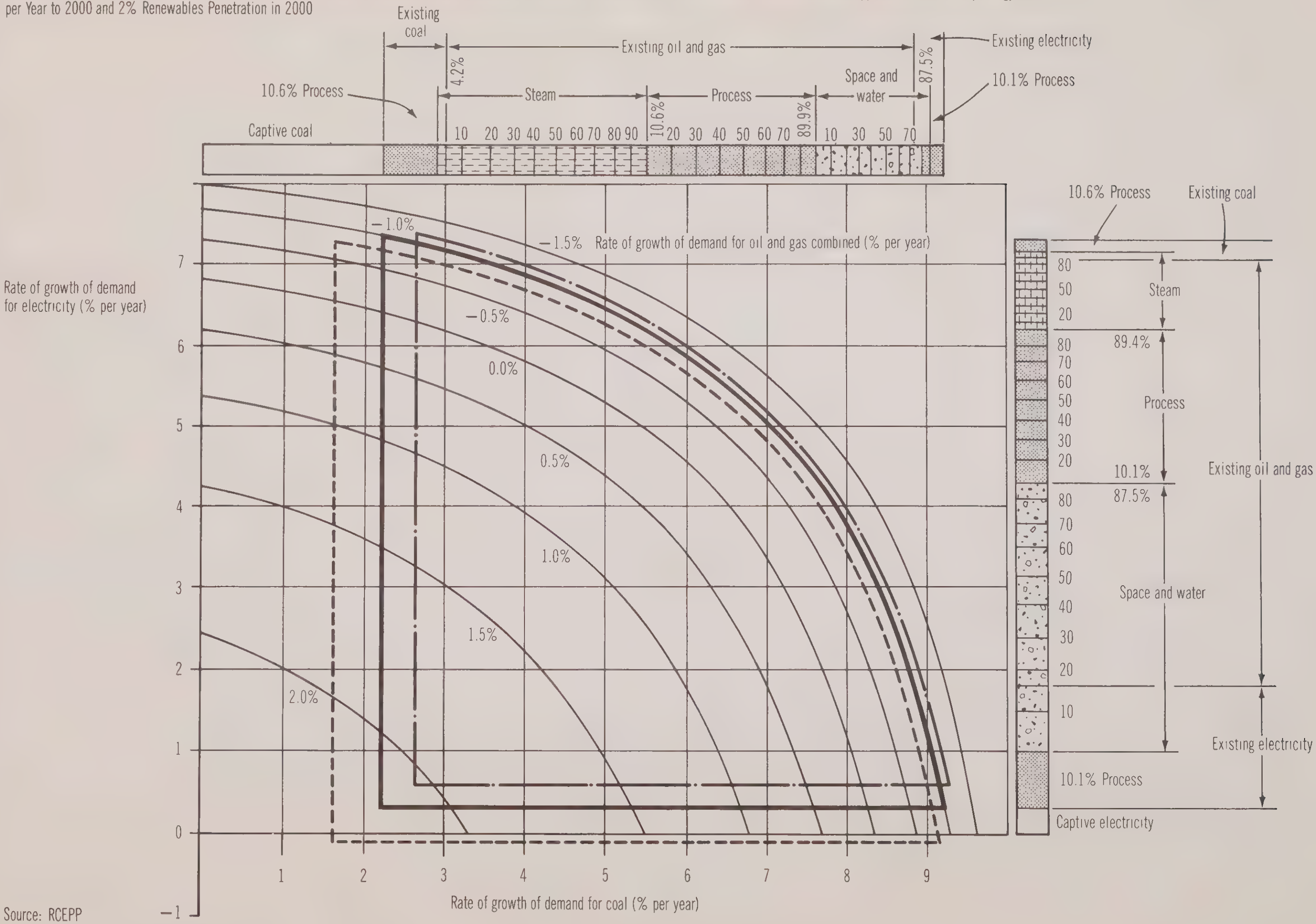
Source: RCEPP

Figure 5.5 Effects of Supply and Other Restrictions. Secondary Energy Growth 2% per Year to 2000 and 2% Renewables Penetration in 2000



Source RCEPP

Figure 5.6 Sensitivity of the Range of Feasible Substitutions among Conventional Fuels to Different Forecasts of the Relative Rates of Growth of Demand in Various Applications. Secondary Energy Growth 2% per Year to 2000 and 2% Renewables Penetration in 2000



Source: RCEPP

Figure 5.7 Reference Projection. Secondary Energy Growth 2% per Year to 2000 and 2% Renewables Penetration in 2000

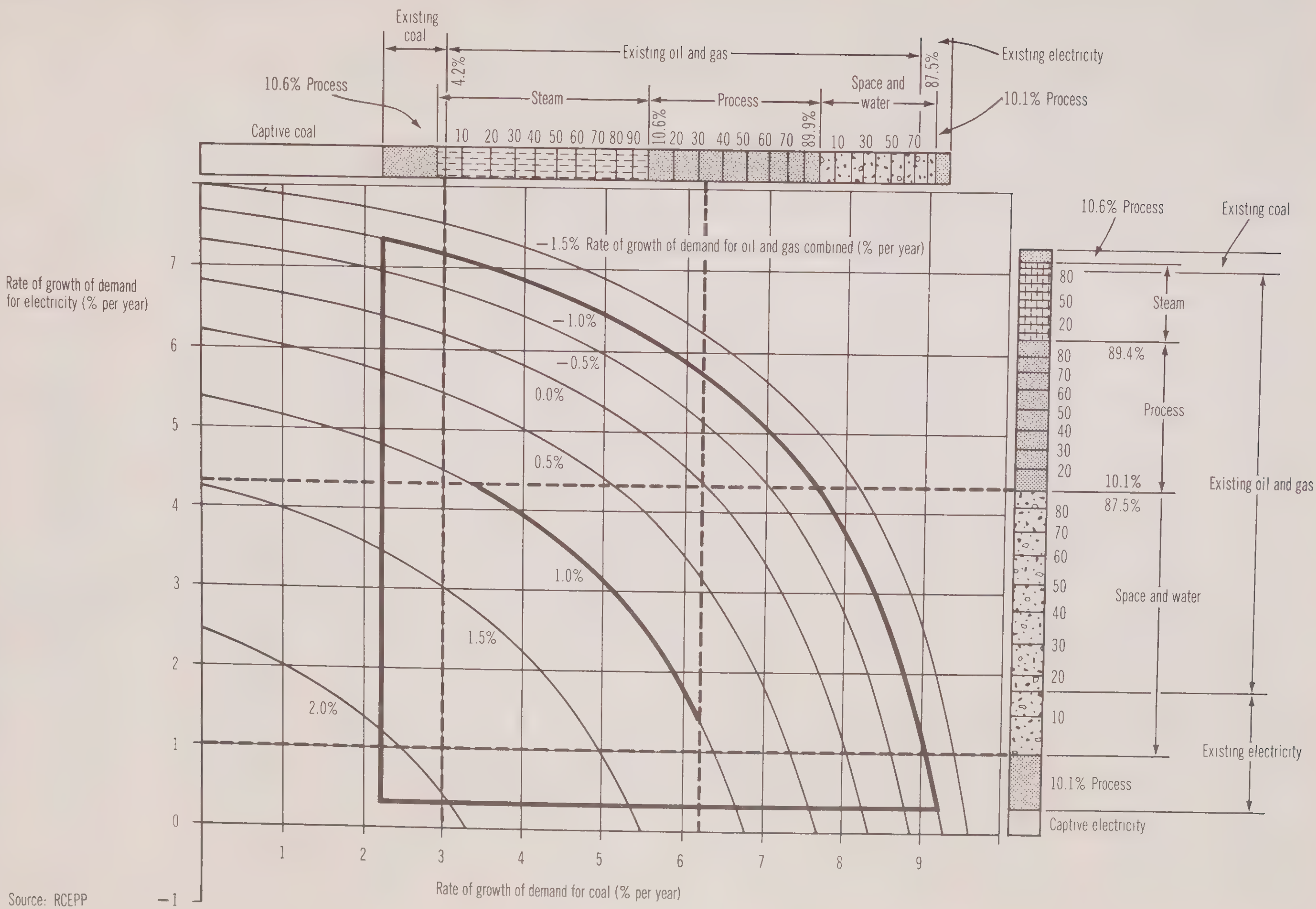
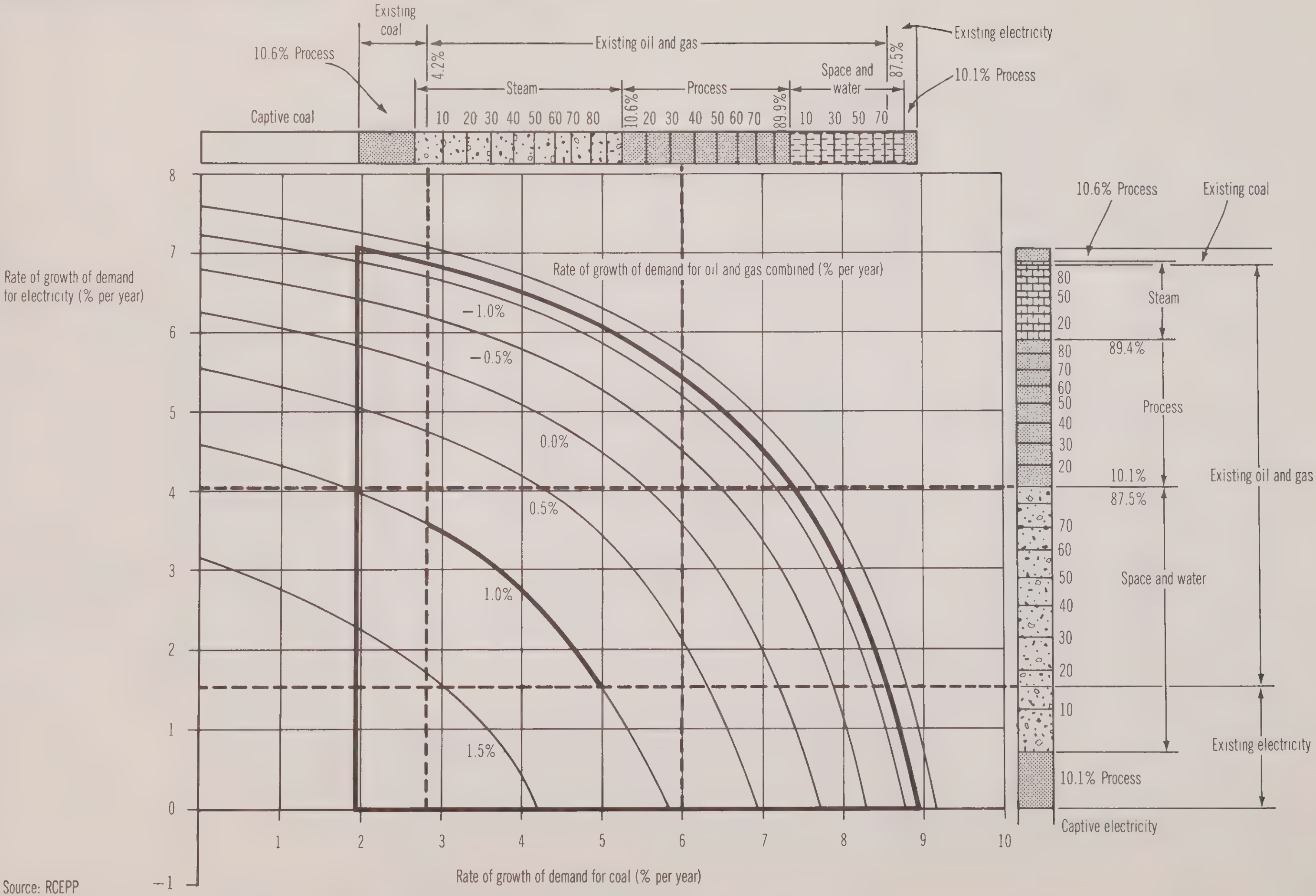


Figure 5.8 Preferred Projection. Secondary Energy Growth 1.75% per Year to 2000 and 2% Renewables Penetration in 2000



Source: RCEPP

Electric Power Planning

The demand for electricity is only one component of the demand for energy. This paper demonstrates that energy policies can have a major impact on the demand for electricity. Energy policies can encourage greater conservation, the provision of additional supplies of various kinds of energy, and substitution among energy sources.

Forecasts of peak load and energy consumption are the starting points for electric power planning. The lead times required for the addition of new generation capacity have grown, the costs of new capacity have increased, and there are growing environmental problems. This has increased the importance of forecasting the demand for electricity.

Responsibility for forecasting peak load and energy consumption – load forecasting – lies with Ontario Hydro. It is the organization best equipped to carry out this activity. It has access to large quantities of data not available to other organizations, such as peak and average loads by region and major customer. If load forecasting, on a province-wide basis, were the responsibility of some other organization, Hydro would still need forecasts of regional and local loads for facilities planning purposes.

Until the early 1970s, Ontario Hydro's electricity demand forecasting performance was outstanding by any measure. The performance of the forecasts for the post-1973 period is much poorer than that of the earlier period. This suggests that the traditional forecasting methods are no longer completely satisfactory. Our review of Hydro's current long-range forecasting methods indicates that there is room for further improvement.

Improvements to the Econometric Model

The econometric model for December peak demand was reviewed in detail in Chapter 3. Several possible improvements to the model were noted there. These included modelling annual rather than December peak, using dummy variables for the post-1973 period, and including a second equation to capture the effects of oil price increases on the rate of economic growth.

End-Use Forecasting Model

Ontario Hydro is currently developing end-use forecasting procedures to complement its existing forecasting methods. We do not know the structure proposed for the end-use forecasting model. We recommend, however, that the end-use model rely primarily on technical relationships. This would permit Hydro to evaluate the effects of a wide range of non-monetary variables on the demand for electricity. The Energy Modeling Forum has made an investigation of 10 American electric load-forecasting models.[1] It found weaknesses with the econometric and the technical (engineering) models. Yet it recommended, among other things, that the econometric and technical approaches be used together, either in a single model or in complementary models.

Forecasting Load Shape

The load forecast assumes that the load factor – the relationship between peak load and average load – remains constant. The load factor is a measure of one aspect of load shape – the seasonal, weekly, and daily fluctuations in demand for electricity.

The load shape may change as a result of factors beyond the control of Ontario Hydro. Greater use of air conditioners or appliances can alter the load shape. Load management can also alter the load shape. Load management includes all measures taken by Hydro to flatten the load shape. It attempts to change the timing, rather than the level, of the demand for electric energy. The effects of load management and of the other factors on load shape are not explicitly forecast and included in the load forecast. This can and should be done.

Conservation Measures

The present Ontario Hydro forecasting model incorporates conservation only as a result of changes in energy prices or *ad hoc* adjustments. Given the projected increase in the importance of conservation measures, this approach is inadequate. An end-use model using technical relationships should allow the

impact of conservation measures to be estimated. Forecasting the nature and extent of future conservation measures involves, to a significant extent, forecasting government policy. This is, then, one area in which the load-forecasting process will be improved by the preparation of a provincial energy policy.

Substitution

At the present time, Ontario Hydro's econometric model incorporates substitution effects by means of projected changes in the relative prices of the different forms of energy. The net effect of these changes is very small. The rate of substitution of electricity for other forms of energy, or vice versa, can be affected by government policy. Building codes, for example, can be used to reduce the amount of oil and natural gas required for space-heating purposes. These fuels are then available in larger quantities for industrial users where they may displace electricity in some uses. It is not likely that the current procedure for estimating substitution effects can be materially improved until the load forecast is prepared in accordance with a provincial energy plan.

Conclusion

Ontario Hydro can improve its electricity demand forecasting methods. It could even relate the demand for electricity to the demands for other forms of energy. However, Hydro's ability to forecast energy policies that affect conservation and substitution among other forms of energy will be limited. The Ministry of Energy will be in a much better position to make these forecasts. Ontario Hydro, therefore, should carry out its electricity demand forecasting within a clearly specified framework of energy policies and a forecast of total energy demand. To provide the total energy demand forecast and the policy framework should be the responsibility of the Ministry of Energy.[2]

Technical Details of Econometric Model

This appendix describes the econometric model used in the 1979 forecasting process. The model is the result of a series of trial models. The model chosen was selected on the basis that it should have good statistical properties, and that it should generally agree with the tenets of basic economic theory and with the results of other models.

Historical data for 1957-78 were used to estimate the model, which applies to the East System primary peak demand.

The description summarizes the main points of technique and then applies these to the particular application.

The Model

Structure

The model relates East System December primary peak demand to variables measuring economic growth, the price of electricity, and the prices of competing forms of energy. Economic variables of this type tend to interact proportionately; hence it is conventional to use a multiplicative model.

By taking logarithms of the variables, the multiplicative model can be converted into a log-linear model – one that is a linear function of the logarithms of the variables. This transformation is made because the log-linear model can be estimated using linear regression and it has the appropriate structure for measures used in statistical inference. In the log-linear form, the estimated coefficients can be interpreted directly as short-term (one-period) elasticities. A second version enables long-term elasticities to be estimated.

Consider the following simple multiplicative model:

$$y = \gamma x^{\beta} u$$

where y is the dependent variable, x is the independent variable, γ and β are coefficients to be estimated, and u is the random error. Taking logarithms yields the following log-linear model:

$$\ln y = \ln \gamma + \beta \ln x + \ln u$$

Short-Term Elasticity

Elasticity (E) is the percentage change in one variable divided by the percentage change in another variable. In the case of our simple model we can write

$$E = \frac{\text{percentage change in y}}{\text{percentage change in x}}$$

$$= \frac{dy/y}{dx/x} = \frac{dy/dx}{y/x}$$

The expression dy/dx is calculus notation for the derivative of y with respect to x. For the simple model we have

$$\frac{dy}{dx} = \gamma \beta x^{\beta-1} u$$

and

$$\frac{y}{x} = \frac{\gamma x^{\beta} u}{x} = \gamma x^{\beta-1} u$$

$$\text{Hence } E = \frac{dy/dx}{y/x} = \frac{\gamma \beta x^{\beta-1} u}{\gamma x^{\beta-1} u} = \beta$$

Thus the coefficients of the independent variables in the log-linear model are direct estimates of the elasticity (for example, the ratio of a proportionate change in demand to a proportionate change in oil price). These are the short-term elasticities, because β reflects the extent to which the change in the independent variable from one period (year) to the next affects the dependent variable over the same

time-span. The full effect of the change may not be reflected in the dependent variable for several periods (years). The long-term elasticity gives the ultimate proportional change in the dependent variable for a unit proportional change in the dependent variable.

Long-Term Elasticity

The long-term elasticities are estimated by means of a technique described by Uri (1978). Let y_t^* denote the long-run equilibrium response due to a change from x_{t-1} to x_t. On the short run (one year), only a part (λ) of the total adjustment occurs.

Thus we have:

$$\frac{y_t}{y_{t-1}} = \left[\frac{y_t^*}{y_{t-1}}\right]^{\lambda}$$

By taking logarithms of both sides, this can be rewritten as:

$$\ln(y_t) - \ln(y_{t-1}) = \lambda\ln(y_t^*) - \lambda\ln(y_{t-1}).$$

The basic model presumes that, in equilibrium:

$$\ln(y_t^*) = \ln(\delta) + \beta\ln(x_t) + \ln(u_t)$$

This equation can be interpreted as meaning that, at a level x_t of the independent variable, the response will be y_t^* in the long term.

The two equations can be combined to give:

$$\ln(y_t) - \ln(y_{t-1}) = \lambda(\alpha + \beta\ln(x_t) + v_t) - \lambda\ln(y_{t-1})$$

where $\alpha = \ln(\delta)$ and $v_t = \ln(u_t)$. Rearranging the terms gives:

$$\ln(y_t) = \lambda\alpha + (1-\lambda)\ln(y_{t-1}) + \lambda\beta\ln(x_t) + \lambda v_t$$

The model specified in this equation is estimated using ordinary least squares.

Let k_1 be the estimated value of the coefficient of $\ln(y_{t-1})$, and let k_2 be the estimated value of the coefficient of $\ln(x_t)$.

Then $k_1 = 1 - \lambda$

and $k_2 = \lambda\beta$

hence $\beta = \frac{k_2}{\lambda} = \frac{k_2}{1-k_1}$ is the estimate of the long-term elasticity.

It is often the case that, for time series data, the errors are serially correlated. An improved estimate can be obtained by correcting for first-order autocorrelation, that is, when each error is correlated with the preceding error. The model is corrected for first order autocorrelation using the Hildreth-Lu technique as outlined below.

Given the model

$$y_t = \alpha + \beta x_t + v_t$$

where t is time, y the dependent variable, x the independent variable, v the disturbance, and α and β the coefficients. The model has first-order autocorrelation if

$$y_t = \alpha + \beta x_t + \rho v_{t-1} + e_t$$

Where ρ is the coefficient of first-order autocorrelation and e_t the uncorrelated disturbance.

In other words, the model has first-order autocorrelation if

$$v_t = \rho v_{t-1} + e_t$$

The unexplained disturbance for the current period is systematically related to the disturbance for the previous period.

Now

$$v_{t-1} = y_{t-1} - \alpha - \beta x_{t-1}$$

so that

$$y_t = \alpha + \beta x_t + \rho(y_{t-1} - \alpha - \beta x_{t-1}) + e_t$$

and

$$y_t - \rho y_{t-1} = \alpha(1-\rho) + \beta(x_t - \rho x_{t-1}) + e_t$$

which yields uncorrelated disturbances, e_t. The Hildreth-Lu technique is an iterative procedure that chooses a "good value" for ρ in the above model. An initial value of ρ is selected and the model estimated. The autocorrelation coefficient and standard error of the estimated model are calculated.

The model is re-estimated using the new estimate of the value of ρ. The autocorrelation coefficient and standard error of the new estimate are calculated. Iterations continue until the standard error is minimized.

It is an essential assumption of regression analysis that the disturbance terms are randomly distributed. If this assumption is not satisfied, the estimated coefficients are biased. First-order autocorrelation of the disturbances is not uncommon in time series models. The Hildreth-Lu technique provides a means of obtaining improved estimates of the coefficients when this type of systematic behaviour is found in the disturbance terms.

Variables (Ontario Hydro) and Data for Model Estimation

Y = Logarithm of East System December primary peak (delivered plus transmission losses), in megawatts.

X_1 = Logarithm of peak charge adjusted to constant 1971 dollars using the GNE index (per FF781120 excluding AIB effect, corrected for INCO strike 1978), in dollars per kilowatt. The data were obtained as follows:

Total revenue: the total dollars received from customers in the system being estimated

Energy wholesale rate: the average mill rate

Annual energy: the total amount of energy delivered

Revenue from demand charge = total revenue – energy wholesale rate × annual energy

$$\text{Demand charge} = \frac{\text{revenue from demand charge}}{\Sigma_{t=1}^{12}(\text{month } t \text{ peak})/12}$$

X_2 = Logarithm of energy wholesale rate; the published wholesale energy charge in mills per kilowatt hour

X_3 = Logarithum of productivity; real Canadian GNE/employee adjusted to constant 1971 dollars.

X_4 = Logarithm of Ontario employment, in thousands.

X_5 = Temperature (°F); the temperature variable is the 5 p.m. temperature recorded at Toronto International Airport.

X_6 = Logarithm of oil price; the oil price is the price in 1971 cents per gallon of No. 2 fuel oil in Toronto.

X_7 = Logarithm of gas price, in 1971 cents per million BTU; the gas price is as quoted at the Toronto city gate.

NOTE: for 1957 and 1958 the gas price is set at 119 and 116, respectively, to compensate for the unavailability of gas as a competitor to electricty for a large part of the Ontario market. This price seeks to be a surrogate for lack of availability while maintaining X_7 as a gas price variable. From 1959 on the price as described above is used.

The model uses lagged variables for demand charge (X_1), energy wholesale rate (X_2), and gas price (X_7). These lags are used because experience has shown that demand does not respond to a price change immediately but takes some time to adjust.

Econometric Model for Short-Term Elasticity

The econometric model thus has the following form

$$\begin{aligned} y_t = \alpha &+ \beta_1 \; x_{1,t-1} + \beta_2 \; x_{2,t-1} + \beta_3 \; x_{3,t} \\ &+ \beta_4 \; x_{4,t} + \beta_5 \; x_{5,t} + \beta_6 \; x_{6,t} \\ &+ \beta_7 \; x_{7,t-1} + v_t \end{aligned}$$

which, when corrected for first-order autocorrelation, becomes

$$
\begin{aligned}
y_t - \rho y_{t-1} = {} & \alpha(1-\rho) + \beta_1(x_{1,t-1} - \rho x_{1,t-2}) \\
& + \beta_2(x_{2,t-1} - \rho x_{2,t-2}) \\
& + \beta_3(x_{3,t} - \rho x_{3,t-1}) \\
& + \beta_4(x_{4,t} - \rho x_{4,t-1}) \\
& + \beta_5(x_{5,t} - \rho x_{5,t-1}) \\
& + \beta_6(x_{6,t} - \rho x_{6,t-1}) \\
& + \beta_7(x_{7,t-1} - \rho x_{7,t-2}) \\
& + e_t
\end{aligned}
$$

Statistical Results – Econometric Model for Short-Term Elasticity

Variable	Notation	Coefficient (elasticity)	Standard error	t-value
Constant		−10.407	2.94	−6.0
Log peak price (lag = 1)	x_1	−0.412	0.040	−10.2
Log energy price (lag = 1)	x_2	−0.127	0.026	−4.8
Log productivity	x_3	1.118	0.156	7.2
Log Ontario employment	x_4	1.448	0.114	12.7
Temperature	x_5	−0.00013	0.000	−0.6
Log oil price	x_6	−0.129	0.051	−2.5
Log gas price (lag = 1)	x_7	−0.043	0.011	−3.9
Correlation coefficient		0.999		
Standard error		0.014		
Durbin-Watson		2.34		
Autocorrelation coefficient		−0.17		
Degrees of freedom		13		

Econometric Model for Long-Term Elasticity

The model for long-term elasticity calculation (corrected for first-order autocorrelation), where $\alpha^* = \lambda\alpha(1-\rho)$, is:

$$
\begin{aligned}
y_t - \rho y_{t-1} = {} & \alpha^* + (1-\lambda)(y_{t-1} - \rho y_{t-2}) \\
& + \lambda\beta_1(x_{1,t-1} - \rho x_{1,t-2}) \\
& + \lambda\beta_2(x_{2,t-1} - \rho x_{2,t-2}) \\
& + \lambda\beta_3(x_{3,t} - \rho x_{3,t-1}) \\
& + \lambda\beta_4(x_{4,t} - \rho x_{4,t-1}) \\
& + \lambda\beta_5(x_{5,t} - \rho x_{5,t-1}) \\
& + \lambda\beta_6(x_{6,t} - \rho x_{6,t-1}) \\
& + \lambda\beta_7(x_{7,t-1} - \rho x_{1,t-2}) \\
& + e_t
\end{aligned}
$$

Statistical Results – Econometric Model for Long-Term Elasticity

Variable	Notation	Coefficient (elasticity)	Standard error	t-value	Long-term elasticity*
Constant		−8.205	5.289	−2.8	
Log primary peak (lag = 1)	y_{t-1}	0.248	0.135	1.8	
Log peak price (lag = 1)	x_1	−0.350	0.050	−7.0	−0.465
Log energy price (lag = 1)	x_2	−0.126	0.023	−5.4	−0.167
Log productivity	x_3	1.011	0.150	6.7	1.34
Log Ontario employment	x_4	0.949	0.289	3.3	1.26
Temperature	x_5	−0.00021	0.000	−1.1	
Log oil price	x_6	−0.076	0.053	−1.4	−0.100
Log gas price (lag = 1)	x_7	−0.031	0.012	−2.7	−0.041
Correlation coefficient		0.999			
Standard error		0.013			
Durbin-Watson		2.40			
Autocorrelation coefficient		−0.18			
Degrees of freedom		12			

*Calculated by dividing the coefficient by 1 − 0.248 = 0.752, e.g., −0.350/0.752 = −0.465.

APPENDIX B

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APPENDIX C

The Demand for Electricity: Some Additional Comments

Dominating the process that will have to be used in the future to determine electricity demand is the impending exhaustion of world oil and natural gas reserves. Vigorous programmes are sure to be mounted at the provincial, national, and international levels to achieve a transition to a new energy régime.

Broad targets for the level of electricity consumption will probably be set as part of comprehensive energy plans developed by central agencies. These plans will be backed up by inducements and regulations that will mobilize our dynamic market system to bring about the desired results.

A comprehensive energy strategy will have to address itself to the factors underlying demand, which may usefully be classified as follows:

A. Economic growth factors
B. Societal structural factors
C. Energy technology and fuel availability factors
D. Societal priority factors

A and B are the societal factors which together determine total energy needs, by end use, and which are in the sphere of non-energy policy-making – unless the energy problem proves to be so severe as to call for economic growth limitation and structural change.

Important A factors are the possibilities that Canada may again experience a major immigration upsurge, and that severely reduced economic growth may be induced by market saturation, disruption of the world economy, or severe pressure on the world's natural resources and ecosystems.

The main B factors that might affect energy intensity are: saturation of the home-heating, automobile, and appliance markets; changed transportation, communication, and housing patterns; an industrial strategy favouring finished manufactures; materials recycling; expanded agriculture induced by world food shortages; and increased tourism. The overall potential for reduced energy intensity is considerable, but it will depend partly on non-energy policy initiatives. Tending to offset these effects somewhat would be increased energy requirements for mineral extraction and separation, and major increases in air transport. Already, from 1959 to 1975, according to Figure 2.3 of the Commission's *Interim Report on Nuclear Power in Ontario*, a significant structural fall in end-use energy intensity occurred at the rate of about 1.0 per cent per annum – probably because of domestic space-heating and appliance saturation.

C and D constitute the realm of energy policy. C determines the set of "energy solutions" that are possible on cost and availability grounds. These solutions consist of different mixes of energy-supply forms (including electricity), inter-fuel substitutions in end uses, and energy-efficiency improvements that can close the oil gap. They correspond to different ways of allocating our energy capital investment dollar.

The following are some important C factors:

- With regard to supply: the relative costs and availability of electricity, coal and coal derivatives, natural gas from tight strata and frontier regions, oil from tar sands, and co-generated electricity and heat
- With regard to substitution in end uses: the choice between electricity, natural gas, and solar in space heating; the choice between electricity and coal in industrial process heat; and the possibility of electrical automobiles and trains
- With regard to conservation, or energy-efficiency improvement: the possibility of a more serious perspective in which conservation is viewed, not in terms of self-denial or penny-pinching, but as a major capital investment programme – and perhaps economic opportunity – to re-equip our economy to operate at a lower energy level without deterioration of living standards

Even in a high-conservation future, a high level of electricity demand is technically feasible, through substitution, in space heating, industrial process heat, and transportation, though cost obstacles might stand in the way.

D reflects social aims, among which trade-offs must be made in the process of selecting an optimum solution from among the C alternatives. The choices are among material living standards, the quality of the physical and social environments, job availability, leisure, guarantees of sustained energy-efficiency, national security, balance of payments, moral considerations, and so on. The starkest example of this trade-off is probably the Hobson's choice between nuclear safety hazards and coal and tar-sands pollution. Large energy-efficiency investments might be selected as a partial alternative to both.

The many issues that must be considered in each of the categories will have a pronounced effect on the demand for electricity. Either a low or a high electricity future is possible. The simple model in Chapter 5 may be used to illustrate the effect and interplay of the issues, especially if presented in a rather more complete form. The concern here is not to predict electricity demand, but to define the process by which it can be targeted, through the resolution of the issues, as part of a comprehensive energy plan.

Hydro Forecasting within an Energy Policy Framework

While a central agency will likely play the leading role in developing the comprehensive plan, the process must provide for input from the many government and other agencies that are involved in the A, B, and D issues.

To assist in the work of constructing a sound, comprehensive energy plan, a good model is essential. Extensive work is needed to evolve such a model. Both the Statistics Canada Long-Term Simulation Model and the Ontario Ministry of Energy Model appear to have potential for further evolution, and this potential should be rapidly exploited. The particular advantage of the Statistics Canada model is that it can, in conjunction with the C energy factors, help in analysing some of the category A, B, and D societal factors. Complementing these models will be other models, like those of Energy, Mines and Resources Canada and the National Energy Board in which the effects of energy prices are considered.

Within this general framework of an energy plan and supporting inducements and regulations, Ontario Hydro would be required to prepare, precisely and in detail, the forecast necessary for planning the electricity supply system. Hydro is equipped for this because of its customer relationships and its access to load statistics. A new end-use-based forecasting method will be required – Hydro is already moving in that direction – to take account of the changing end-use patterns and of the energy-efficiency improvements that will characterize the transformation of the energy system in the coming decades. Such end-use forecasting will also permit forecasting of the basic annual load shape and factor (now assumed to be constant), important for optimal electric power system design, and, moreover, it will make Hydro forecasting compatible with the planning and targeting of the central agency, which must be performed on energy models designed on an end-use basis. Indeed, according to the study "Canadian Energy: the Next 20 Years and Beyond", issued by the Institute for Research on Public Policy in January 1980, the possibility actually exists of planning the electric power system load factor as part of a comprehensive energy strategy. At present, the 30 per cent or lower load factor of electricity in space heating is an obstacle to major expansion of electricity in this use. Without such expansion, as the model in Chapter 5 shows, the possibility for large electricity demand growth is severely limited. According to the study, a hybrid electric-fossil system might overcome the difficulty and very significantly raise both the load factor and the capacity factor. Without end-use-based forecasting, it is not easy for Hydro fully to evaluate such suggestions. End-use forecasting will shift the focus of forecasting away from annual peak load to total energy and the variation in the rate at which this energy is delivered in the course of the year.

The Possibility of a Surprisingly Low Energy Future

The conclusion reached in this volume is that the most probable rate of growth of end-use energy to the year 2000 is 1.75 per cent per annum, along with an electric-energy growth rate of 3.25 per cent ± 0.5 per cent per annum.

There is considerable evidence that the structural, or B category, factors will produce a reduction in energy intensity, which should be added to the 1.55 per cent per annum energy-efficiency improvement assumed in this volume. (The latter assumed a zero per cent energy-intensity reduction on structural grounds.) Several projections, including those based on the two models just referred to, show this structural element to be between 0.5 and 1.0 per cent per annum, mainly on grounds of consumer market saturation. This suggests an end-use energy growth rate of about 1.0 to 1.2 per cent per annum – in fact, a per capita energy growth of about zero per cent.

This is the same as the low scenario for North America favoured in the important global energy study of the International Institute for Applied Systems Analysis in Laxenburg, Austria. This study regards its high-scenario, 0.6 per cent per capita, or 1.6 per cent total end-use, energy growth as an upper limit.

It seems reasonable to suggest for Ontario a possible end-use energy growth range of 0.75 to 2.0 per cent per annum, allowing for the possibility, at the lower end, of economic growth depressed by market saturation or economic stagnation and, at the upper end, of an upsurge in immigration, and allowing for Canada's relatively favourable energy supply situation, which might distract attention from conservation. However, if the 1.5 per cent per annum energy-efficiency improvement can be as easily attained as the Commission's research indicated, it is difficult to see an energy growth rate higher than, say, 1.2 per cent per annum.

Under the total energy range suggested above, one can envisage an electric energy growth rate ranging from, say, 1.6 to 3.6 per cent per annum, or, if major electrification is undertaken (for example, on environmental grounds if the nuclear safety problem can be solved), a range from 2.75 to 4.5 per cent per annum.

These figures are purely illustrative. The main concern here has been to demonstrate the relevant factors that must be considered, and the type of public-policy process that must be developed to produce an optimal electricity solution for Ontario.

Michael Jaffey

Notes to Chapters

Notes to Chapter One

1. "The Demand for Electric Power" (a summary of Issue Paper No. 2). Toronto: RCEPP, December 1976, p. 1.
2. RCEPP Exhibit 89, p. 2.
3. RCEPP Exhibit 89, p. 3.
4. RCEPP transcript, vol. 166, p. 23977.
5. RCEPP Exhibit 184, p. 10.
6. RCEPP Exhibit 334, p. 17.
7. RCEPP transcript, vol. 238, p. 37675.
8. RCEPP Exhibit 334, p. 2.
9. RCEPP Exhibit 129, p. 2.

Notes to Chapter Two

1. *Demographic Bulletin.* Toronto: Department of Treasury, Economics and Intergovernmental Affairs. October 1978, chart 3.
2. *Ibid.*
3. The data are available from the following Statistics Canada publications:
   – Provincial GDP at market prices – *Provincial Economic Accounts* – cat. no. 13-213, table 1.
   – National GNE implicit price index, Toronto consumer price index, and employment in Ontario – *Canadian Statistical Review.*
4. The difference between the two growth rates is a convenient approximation. The precise definition is the ratio of the growth factors, i.e., 1.04/1.0192 equals 1.0204 per cent per year.
5. The precise calculation gives the identical result: 1.04/1.02 equals 1.0196 per cent.

Notes to Chapter Three

1. Ontario Hydro uses the term "primary energy" for the amount of energy generated. That definition will be used throughout this chapter. Primary energy may mean other things in other contexts. It often refers, for example, to energy in the fossil fuels used by thermal generating stations. The energy in the fossil fuels is about three times greater than the electric energy generated.
2. This is calculated as follows: Average load = 95.372 GW.h divided by 8.760 hours per year = 10.887 GW or 10,887 MW. Peak load = 16,371 MW. Load factor = (10,887/16,371) × 100 = 66.5 per cent.
3. *The 1979 Medium Term Forecast.* Toronto: Ontario Hydro, February 1979, p. 2.
4. Double exponential smoothing is a way of reducing random variation in historical data so that the trend and cycles may be seen more clearly.
5. See, for example, RCEPP transcript, vol. 253, p. 40,025, and transcript vol. 256, p. 40,295.
6. *Ibid.* Pp. 40,033, 40,040, and 40,218-40,220.
7. *Potential Long Term Growth of Demand in the East System.* Toronto: Ontario Hydro, February 1979, p. 5.

Notes to Chapter Four

1. Workshop on Alternative Energy Strategies, "Energy Demand Studies: Major Consuming Countries,". Cambridge, Massachusetts: MIT Press, 1976.
2. *Energy Demand Projections – A Total Energy Approach.* Report ER-77-74. Ottawa: Department of Energy, Mines and Resources, June 1977.
3. The model is described by R.A. Preece, L.B. Harsanyi, and H.M. Webster in "The Energy Demand Forecasting System of the National Energy Board", a paper presented to the Canadian Energy Policy Modelling Conference, Vancouver, 1978. The projections are from *Canadian Oil Supply and Requirements.* Ottawa: National Energy Board, September 1978.
4. R. Clayton, *et al.*, "Canadian Energy: The Next 20 Years and Beyond", a review draft. Montreal: Institute for Research on Public Policy, 1978.
5. R.B. Hoffman, "Users' Guide to the Statistics Canada Long Term Simulation Model", and S.F. Gribble and K.E. Hamilton, "Energy Futures: Scenarios and Postulations". Ottawa: Statistics Canada, 1977.

6. J.E. Gander and F.W. Belaire, *Energy Futures for Canadians.* Report EP 78-1. Ottawa: Energy, Mines and Resources, 1978.
7. D.B. Brooks, *Economic Impact of Low Energy Growth in Canada: An Initial Analysis.* Discussion Paper No. 126. Ottawa: Economic Council of Canada, December 1978.
8. Four models of final energy demand were developed by or for the Ontario Ministry of Energy during 1976 and 1977. Demand projections using these models were commissioned by the Royal Commission on Electric Power Planning. The results are presented in E.F. Haites and J.L. Sullivan, "Projections of the Final Demand for Energy in Ontario to the Year 2000", part one, March 1978, and E.F. Haites, "Projections of the Final Demand for Energy in Ontario to the Year 2000", part two, May 1978. Toronto: RCEPP.
9. R. Crow, P. Szegedy-Maszak, and C. Conway, *Energy Planning in a Conserver Society, The Future's Not What It Used to Be.* Toronto: Energy Probe, February 1978. *Energy Planning in a Conserver Society, Implementation Strategies.* Toronto: Energy Probe, January 1979.
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11. *Planning Electric Power for Ontario.* Toronto: Sierra Club of Ontario, September 1978, p. 19.

Notes to Chapter Five

1. E.F. Haites and J.L. Sullivan, "Projections of the Final Demand for Energy in Ontario to the Year 2000", part one, March 1978; and E.F. Haites, "Projections of the Final Demand for Energy in Ontario to the Year 2000", part two, May 1978, Toronto: RCEPP.
2. "Energy Utilization and the Role of Electricity". Memorandum to the RCEPP. Toronto: Ontario Hydro, April 1976. Table 6.2-15.
3. E.F. Haites, "Projections of the Final Demand for Energy in Ontario to the Year 2000", part two, May 1978. Toronto: RCEPP.
4. R. Clayton, *et. al.*, "Canadian Energy: The Next 20 Years and Beyond". Review draft. Montreal: Institute for Research on Public Policy, 1978, p. 16.

Notes to Chapter Six

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2. James E. Dooley, "Review of the Energy Demand Forecasting Methods Used by Ontario Hydro and the Ministry of Treasury, Economics and Intergovernmental Affairs". Toronto: RCEPP, April 1977.